ELWHA RIVER HYDROELECTRIC SYSTEM
Port Angeles Vic.
Clallam County
Washington

HAER No. WA-130

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Historic American Engineering Record
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HISTORIC AMERICAN ENGINEERING RECORD

ELWHA RIVER HYDROELECTRIC SYSTEM

HAER No. WA-130

Location:	Elwha River, Clallam County, Washington Quad: Elwha, WA UTM: 10/458640/5326740 (Elwha) 10/455340/5317710 (Glines)
Date of Construction:	1910-1927
Fabricator:	L.L. Summers and Company, Charles V. Seastone and Daniel W. Mead; Thebo, Starr and Anderton.
Present Owner:	James River Corporation
Present Use:	Hydroelectric plant
Significance:	Developed between 1910 and 1927, the Elwha River Hydroelectric System consists of two power plants, the Elwha and Glines Canyon facilities. This hydroelectric system influenced the industrial growth of Washington State's Olympic Peninsula and typified hydroelectric development in the early twentieth century. In addition, it owed its existence, primarily, to the efforts of Port Angeles entrepreneur, Thomas T. Aldwell.
Historian:	David Louter, September 1995

Project Information:

In 1992, Congress passed the Elwha River Ecosystem and Fisheries Restoration Act (Public Law 102-495). The act directed the Secretary of the Interior to study ways to restore the native anadromous fisheries and ecosystem of the Elwha River. In 1994, the Department of the Interior completed that study, and the Secretary of the Interior determined that the removal of the dams was feasible and necessary to restore the fisheries and ecosystem of the river. Such an action would also promote the federal trust responsibility for affected tribes, such as the Elwha S'Klallam Tribe, who base much of their culture and economy on the salmon of the Elwha River. In 1995, the Historic American Engineering Record (HAER) began a historical and architectural documentation project of the Elwha River Hydroelectric System as part of the overall documentation being undertaken in compliance with the National Environmental Policy Act and Section 106 of the National Historic Preservation Act.

CHRONOLOGY

1910	L.L. Summers and Company begin construction of the Elwha River Hydroelectric Dam and Plant for the Olympic Power Company.
1912	The Elwha Dam's foundation blows out shortly before the power plant was scheduled to go on line.
1914	Repairs completed, Elwha power station goes on line.
1916	Financially troubled Olympic Power Company is reorganized as the Northwestern Power and Manufacturing Company.
1919	Final repairs to leaking reservoir completed increasing water storage capacity and power generation for the Elwha plant. Zellerbach Paper Company purchases the power station for its new Port Angeles mill, the Washington Pulp and Paper Company.
1922	An annex to the Elwha powerhouse completed, two new generating units are added to meet the needs of an expanding Washington Pulp and Paper Company.
1924	Northwestern Power and Manufacturing Company reorganized as Northwestern Power and Light Company.
1927	The Glines Canyon Hydroelectric Dam and Plant are completed and the new facility comes on line, supplying power to Washington Pulp and Paper Company.
1928	Northwestern Power and Light Company settles its patent infringement suit with the Constant Angle Arch Dam Company over the design of the Glines Canyon Dam.
1949	Elwha River Hydroelectric System becomes incorporated into a regional power system managed by the Bonneville Power Administration.
1992	Federal law passes directing the Secretary of the Interior to restore the Elwha River's ecosystem and fisheries, after some twenty years of disputes over licensing the Elwha power plants.

Introduction

The Elwha River Hydroelectric System, consisting of the Elwha and Glines Canyon facilities, influenced the industrial growth of Washington State's Olympic Peninsula. Spearheaded by Thomas T. Aldwell in the 1890s, the Elwha project typified hydroelectric development in the early twentieth century. Aldwell, an entrepreneur living in Port Angeles, formed the Olympic Power Company with George A. Glines in 1910, and with financing from Chicago investors, completed the Elwha power station in 1914. Throughout its development, the project suffered setbacks related to the design and construction of the dam's foundation. The dam foundation's failure and reconstruction drew considerable interest from engineering circles, but at work here was more than a technological problem solved by experts, for there were social considerations as well. The dam's problems pitted Aldwell against the engineers originally hired to build the installation. In this respect, the power station's history displayed the difficulties faced by individual developers in the early twentieth century, a time when experts and large corporations exerted more control over everyday life and led the development of such expensive and involved projects as hydroelectric power plants.

The first private hydroelectric facility on the Olympic Peninsula, the Elwha power plant supplied power to most of the peninsula's residential, commercial, and industrial users. It played an especially important role in supplying power to, and helping to open up, the pulp and paper industry in the region after World War I. In the mid-1920s, the Northwestern Power and Light Company (the former Olympic Power Company) built a second power station at Glines Canyon to meet growing demands. This second station was noteworthy for its arch dam and its semi-automatic system that linked it with the Elwha plant. The Glines Canyon power plant went on line in 1927 specifically to supply power to Washington Pulp and Paper Company in Port Angeles. Power company officials planned to develop more hydroelectric facilities on the Elwha River, but the advent of regional power networks and large multiple-purpose dams in the 1930s and 1940s effectively ended the expansion of local systems like the one on the Elwha River. Still in operation, the Elwha River Hydroelectric System tells the story of one individual's vision, the evolution of hydroelectric power systems, and the pursuit of economic growth. But the hydroelectric system's presence also tells another story, one about changing environmental values, namely concerns over the loss of the river's fisheries, which might lead to the removal of the power stations altogether.

A Short History of the Elwha River Valley

The Elwha River rises deep in the Olympic Mountains on Washington State's Olympic Peninsula. Fed by glaciers, snowmelt, and rainfall, the Elwha flows in a northerly direction for 45 miles before it empties into the Strait of Juan de Fuca. Its major tributaries are the Hayes, Goldie, Lost, and Lillian rivers, and together they form a watershed of more than 300 square miles. The Elwha runs a steep course. From the high peaks of the Olympics, with elevations over 6,000', it rushes down to sea level alternating between narrow canyons and broad alluvial valleys.[1]

Until the late nineteenth century, the Elwha was unknown to all but the Central Coast Salish. It was one of the many rivers draining the rugged interior mountains of the Olympic Peninsula, one of the last areas to be explored by Europeans and Anglo Americans in the contiguous United States. The mythical Northwest Passage, an inland waterway crossing North America, interested these explorers more than the peninsula's harsh climate and topography. The region's wet, mountainous, and densely forested landscape, in fact, deterred many from entering this wilderness landscape.[2] When residents of the Puget Sound began to explore the peninsula in the late 1870s, they ventured inland from the coastal shorelines up the major river valleys. They were attracted to the region's mysterious character and the possibility that it contained gold and other valuable minerals. Some of the more famous expeditions were conducted by U.S. Army Second Lieutenant Joseph P. O'Neil and a group of explorers sponsored by the Seattle Press newspaper; both parties encountered the Elwha River during their travels.[3]

Travel up the river was hard work for these explorers. Large trees blocked their path, inclement weather tested their endurance, and muddy trails slowed their progress, to name a few hindrances. On their way up the Elwha in the winter of 1889 and 1890, for example, members of the Press party hauled, for short time, a flatboat named Gertie loaded with their supplies. This labor itself proved to be both arduous and dangerous, and was exacerbated by unremitting rain, snow, and cold weather. In their struggles with the boat, expedition members continually plunged into the river's freezing water to portage, to guide their craft through white water, or to save it from capsizing. Early in their trip, the boat swamped in the icy-cold rapids of today's Aldwell Canyon (location of the Elwha power plant), pitching all hands overboard and submerging their supplies.[4]

The widely publicized O'Neil and Press expeditions were not the only parties to enter the Elwha River Valley in the 1890s and early 1900s. Miners passed through the region hoping to find precious metals. Scientists also traversed the Elwha Valley as they surveyed the newly established Olympic Forest Reserve (1897), which embraced most of the upper Elwha; they also studied the flora and fauna of the region, and conquered some of the unnamed peaks surrounding Mount Olympus. Similarly, hunters, fishermen, mountaineers, and sightseers visited the Elwha country for its abundant wildlife, splendid beauty, and wild surroundings. As one visitor commented after a trip up the Elwha Valley, "Wild Wood, wild berries, wild life; there's nothing tame in the Olympics." For the tourist who desired a tamer experience, resorts like the Olympic Hot Springs or the Waumila Lodge catered to their needs. Although the creation of the Mount Olympus National Monument in 1909 curtailed some of these commercial activities in the upper reaches of the Elwha, such as hunting and mining, it remained an important place for scenic beauty and outdoor life.[5]

Homesteaders appeared on the Olympic Peninsula and in the Elwha Valley around the same time as the region's explorers and outdoor enthusiasts. Although the lower Elwha, near the river's mouth, was considered one of the oldest settled parts of Clallam County in 1885, the same could not be said for the upper Elwha. Settlement occurred there first in the late 1880s and continued through the turn of the century. Like the other diverse groups who encountered the Elwha, homesteaders found the Elwha Valley a natural pathway into the Olympic interior. Homesteaders took up claims along the Elwha from the vicinity of Indian Creek as far up the valley as Lillian River. They cleared land along the river bottom and built modest cabins, outbuildings, fences, and primitive roads and bridges along and across the river and its tributaries. They established orchards, gardens, and pastures, and raised livestock and barnyard animals. One rather eccentric resident, "Doc" A. Ludden, even raised bees.[6]

Life at best was hard, and only the strong, clever, and lucky seem to have survived for any length of time. Even when they could build on the labors of previous settlers, men and women alike had to look beyond their farms to find other sources of income. But their options were rather limited. Miners never realized the vast wealth envisioned by early promoters of the peninsula and industries never materialized on the Elwha. Similarly, the timber industry failed to gain a strong foothold in the densely forested river valleys of the peninsula like the Elwha, because it was too remote and the logging technology too primitive to harvest the giant trees on a large scale. The presence of the forest reserve also restricted logging operations. Consequently, Elwha homesteaders engaged in everything from hunting predators for bounties to operating hostelries for hikers, hunters, and fishermen who traveled the Elwha River trail. In these and other ways, Elwha settlers supplemented what the river valley could not produce.[7]

More than the environment restricted the lifestyles and livelihoods of early Elwha residents. The presence of the Olympic Forest Reserve and later the national monument radically limited settlement. After the forest reserve was established and subsequently enlarged, settlers faced uncertain times both economically and psychologically living on lands managed by the federal government. Many asked for exclusions and others simply abandoned their homes and farms in this economically marginal and remote part of the peninsula.[8] By the first decades of the twentieth century, they would all be gone from the valley, with only a few structures and clearings to mark their presence.

Thomas T. Aldwell, Port Angeles, and the Development of the Elwha for Hydroelectric Power

During the years that it was being explored, settled, and managed in part by the federal government, the Elwha River was also harnessed for hydroelectric power, a form of resource development which proved to be more successful than any other. The electricity generated on the Elwha greatly affected the industrial development of Port Angeles and the growth of the northern Olympic Peninsula. The person who was primarily responsible for this was Thomas T. Aldwell. Aldwell was a self-made entrepreneur and developer who came to live in Port Angeles in 1890. Innovative and opportunistic like so many men of his time, Aldwell sought to make his "fortune" in the American West and chose Port Angeles to fulfill his dream. He held a variety of jobs--newspaperman, mill worker, real estate agent, and politician--but he "devoted his tireless, driving energy toward developing electric power." For, as George Savage suggested, Aldwell's dream extended beyond just his own fortune to the future of Port Angeles and the Olympic Peninsula.[9]

Thomas Aldwell was born in Toronto, Canada, in 1868. As a young man, he recalled in his autobiography, he "could not endure failure." He grew up believing that competition and fighting were essential to one's survival in the world, beliefs he carried with him throughout his life. Coming of age when the Canadian Pacific Railway reached the Pacific Coast in 1885, Aldwell fully imbibed the romantic image of the western frontier portrayed in the railroad's promotional literature and the fantastic stories reported in booster pamphlets. After working as a banker for four years in his native Ontario, he grew restless with his sedate life. He longed to go West, to find adventure, to make something of his own. He left Canada and headed for the western United States and Washington State, stopping first in Seattle and then in Port Townsend. These cities, though bustling places for business, "were not the frontier any more." He pushed on to Port Angeles, on the northern tip of the remote Olympic Peninsula. He had heard of this town and thought it was an attractive place but too far removed from business opportunities. When he arrived in 1890, however, he found what he was looking for--"a wild frontier town"--a place to begin anew, to create something, and to partake in that nineteenth-century virtue, progress.[10]

Almost from the moment he set foot in Port Angeles at the age of 22, Aldwell participated in shaping its future as an industrial town. He joined the land boom the town was experiencing soon after he arrived, illegally squatting on the government reservation surrounding the small town. The Port Angeles townsite, located on the harbor created by Ediz Hook, had been originally set aside by President Abraham Lincoln in 1862 as a lighthouse and military reserve. Lincoln not only proclaimed it a "National City," but also envisioned that the sale of its lots might help replenish the federal treasury depleted by the Civil War.[11] In 1891, the federal government opened the reservation to homesteading and granted the squatters legal ownership of their lots. Aldwell proved up on his lots and bought several others, launching his work in real estate speculation, a natural calling and a financial mainstay throughout his life.[12]

Aldwell's ownership of property gave him a sense of permanence, a sense, he said, of "belonging to a place." For this reason, he wanted "to control more and more of it, directly or indirectly." His acquisitive nature led him to take an active role in public life and business affairs. He also belonged to an informal group of young and ambitious men at the turn of the century who imagined the possibilities for Port Angeles and the peninsula. They talked freely about bringing a railroad to the region, building a thriving port, creating a tourist industry around the scenic beauties of the Olympics, and flooding the country with electricity and power. In time, Aldwell and his associates realized many of their goals, but none proved so important for Aldwell, perhaps, as the production of hydroelectric power, for it symbolized a future of limitless economic development.[13]

During the land boom of 1890, Aldwell purchased a homestead on the Elwha River, seven miles west of town, which would eventually become the site of a power plant. It seemed like a good investment since sites a few miles from town were going for "$100 or more an acre, sight unseen."[14] Although he had no plans to settle on the Elwha like other homesteaders in the valley, he did not immediately foresee it as a power site but as a place to retreat to nature. For several years, he lost himself in the Elwha's grandeur. His claim was located in the bottom of a canyon along the river, and he freely expressed an appreciation for its scenic beauty. He described a lovely, picturesque scene. A small cabin sat on the land and just below it, "the Elwha River thundered" through the canyon. There was also a spring nearby with

> crystal clear water, overhung by vine maples....The scintillating rays of sun were coming through the branches and sparkling on the water. My life had taken me to schools, to cities, to business, but suddenly that spring embodied all of life and beauty I thought I'd ever want.[15]

He paid $300 for the claim, which must have seemed crazy at the time, he said. Yet he remembered with affection those early days visiting his land. Those "days packing into the Elwha," he wrote, bonded him to the Northwest. By carrying his own supplies, fording the river before bridges were built, and resting on his back beneath the trees, he grew close to the Elwha country through physical exercise and self-reliance, virtues of the frontier life he valued. In that experience, he satisfied the needs for the outdoor life so many in the Progressive era desired, a sedative for their urban lives. Certainly, as the following passage suggests, Aldwell found that on the Elwha: "The needled covered earth, the patterned tree branches, the sky, the fresh bracing woods' smell--all seemed to make me a part of the earth I rested on."[16]

By 1894, he was actively promoting the growth of Port Angeles and the northern peninsula, not just as a visionary discussing his plans with other ambitious people, but by buying land in town and along the shores of Lake Crescent, and becoming a citizen so he could enter political office as county auditor. He also managed a local newspaper in 1894, and it was there he met R.M. Brayne. In the mid-1880s, Brayne owned the Falls Pulp Company, one of the mills on the Youngs River in Oregon, which he operated with a small water power plant. After meeting and talking with Brayne, Aldwell struck on the idea: "A pulp mill!" "A newspaper could do much to build a town, but industry was what was really needed," and what industry needed "was power."[17]

Aldwell saw his claim in a different light now. He recognized that it had potential as a site for water power "because of the volume of the river and the steep walls of the canyon." After Brayne informed Aldwell that he was interested in finding a power site, Aldwell showed him the Elwha claim. Brayne liked what he saw and confirmed his new acquaintance's idea about the site's power potential. Faced with what today might seem a difficult decision, whether to preserve nature unmodified--in a state he so adored--or to develop it, Aldwell easily decided on the latter. "Suddenly," he exclaimed, "the Elwha was no longer a wild stream crashing down to the Strait; the Elwha was peace and power and civilization."[18]

Aldwell and Brayne formed a partnership, each with half interest, with the aim of developing a hydroelectric power plant and reservoir on the Elwha. Brayne purchased a half interest in Aldwell's claim and financed the purchase of land three miles up river from the canyon which would be flooded by the dam. Aldwell's job was to acquire the property. The new partners kept their project a carefully guarded secret. For this reason, over the next twelve years, Aldwell quietly bought the land for the Elwha project to prevent land prices from rising, and most likely to head off other potential claims for water rights on the Elwha. The two men also hired their own engineers to survey the power potential of the Elwha site. Despite the secrecy of Aldwell and his associates, however, the Elwha's water power potential attracted the attention of the federal government. Engineers working for the U.S. Geological Survey and U.S. Reclamation Service conducted their own surveys of the Elwha's power potential around the same time, confirming the findings of Aldwell and Braynes' experts. Even the North Pacific Railroad showed an interest in the river and hired an engineer to conduct a thorough report of its water power possibilities. Their collective conclusions were promising, suggesting that a power site at Aldwell's canyon would permit the development of 14,000 to 25,000 horsepower.[19]

The importance with which Thomas Aldwell regarded his power site had broad implications, involving complex matters of technology, urban growth, and progressive reform, for as the historian Thomas P. Hughes asserted, the evolution of electric power systems, like the experience with other forms of technology, embraced "both causes and effects of social change."[20] At the turn of the century, hydroelectricity epitomized one form of technological change, and it was experiencing rapid growth. It combined the two independent technologies of waterpower and electricity in the 1880s, and by the 1890s advances in the areas of electric light and power development made hydroelectricity widely attractive to power producers and developers of arc and incandescent lighting systems throughout the country.[21]

Some of these improvements in technology included the development of the large capacity hydroturbogenerator, alternating current, and high-voltage, long-distance transmission lines. All of these innovations sparked the interest of engineers and entrepreneurs who wanted to construct hydroelectric facilities in locations far from urban-industrial centers. The widely-publicized Niagara Falls project set the precedent for this design in 1895, but the implications were more significant for western states where potential power sites were located in mountain ranges far from centers of demand. In fact, the West--a land of vast spaces and comparatively small pockets of population--witnessed most of the pioneering applications of remote power production and long-distance transmission.[22]

Engineering advances such as these attracted power companies and entrepreneurs to Washington State's mountainous terrain, abundant rainfall, and plentiful rivers. Their interest in hydroelectricity was also understandable because of the Pacific Northwest's relative paucity of coal, all of which led the region to rely more extensively on hydroelectricity than other sections of the nation.[23]

Power developers moved quickly to exploit the state's rich hydroelectric sites. In particular, they sought to supply electric power to Washington's fastest growing and largest cities--Seattle, Tacoma, Bellingham, and Spokane. Two representative companies whose operations reflected both local and national trends were the Puget Sound Power and Light Company and the Washington Water Power Company--Washington's largest and oldest power companies, which began their operations in the late 1880s and early 1900s. At first, the companies operated direct and alternating current systems powered by steam-driven dynamos. The Seattle Electric Company, parent company of the Puget Sound Power and Light Company, for example, produced the first commercial electricity for Washington in 1886, providing Seattle with incandescent lighting. Hydroelectric power generation soon followed. By 1889, the Washington Water Power Company produced the state's first commercial hydroelectric power for Spokane's arc lighting system. The Puget Sound Power and Light Company was not far behind, building its hydroelectric plant at Electron on the Puyallup River, which supplied Tacoma and Seattle in 1904.[24]

Hydroelectric plants, such as the Snoqualmie Falls Power Plant, demonstrated the feasibility of transmitting power over long distances in Washington State, particularly since the rugged Cascade Mountains contained some of the finest hydroelectric sites. Completed in 1899, the Snoqualmie plant was one of the region's earliest long-distance systems; it transmitted 30,000 volts over a thirty-five-mile line to power trolleys and manufacturing industries in Seattle and Tacoma.[25]

These kind of power facilities signified more than engineering accomplishments in the minds of power developers; they also signified economic potential. In addition to lighting systems, both small and large light and power companies built hydroelectric stations to supply the booming traction industry in the late 1890s and early 1900s. Along with the expansion of interurban railways arose the demand for power from other commercial, industrial, and domestic users during this era, especially with the widespread use of electrical appliances. Some local boosters in the Pacific Northwest expressed a heady confidence in future growth and the role the region's "white coal" would play in that development.[26]

Still another aspect of hydroelectric power in the Northwest was municipal ownership. The issue touched on profound changes in American life in which cities played a dominant role. The movement for municipal ownership in the Northwest and across the country grew in response to the problems associated with rapid urbanization. In the two decades immediately preceding and following the turn of the century, residents of the nation's cities found themselves living in overcrowded conditions, confronting problems of public health, sanitation, transportation, police and fire protection, water supply, and lighting. In their "search for order," middle-class citizens formed political, business, and social organizations to improve living conditions. Many of these organizations labeled themselves Progressives and espoused a platform that proclaimed municipally-controlled power production as more efficient and less expensive than power produced by private firms. Most importantly, these advocates argued that municipally-controlled plants would better serve the public welfare. Private utility companies, it was argued, provided poor and limited service, charged exorbitant rates, lacked any sense of public responsibility, and represented the political corruption associated with monopolies.[27] A direct outcome of this reform movement was the establishment of two major municipal utilities in Washington State serving Seattle and Tacoma. Both produced hydroelectric power in the early 1900s and, as in the case of Seattle City Light, often faced bitter competition from private firms.[28]

It was against this backdrop that Thomas Aldwell conceived of and planned for his hydroelectric project on the Elwha River. With the advent of high-head dams and long-distance transmission lines, hydroelectric power could fuel the growth of western cities like Port Angeles and turn tidy profits for its boosters. The image of the American West as a rural landscape sometimes obscures the fact that the region's cities, along with corporations and federal bureaucracies, formed new centers of power governing the West's development. Western cities exerted their influence far beyond their boundaries, often controlling distant resources to serve their own needs for growth. To meet their water supply needs, cities such as Los Angeles drained the Owens Valley and San Francisco dammed the remarkable Hetch Hetchy Valley in Yosemite National Park. And to meet their needs for power, other western cities dammed river canyons to produce hydroelectricity for lighting and industry.[29]

Unlike power projects in other parts of Washington, the Elwha plant would be constructed to spur industrial development rather than meet existing demands. Industry and power generation functioned on a primitive level in the Port Angeles region in the late nineteenth and early twentieth centuries. Up until the turn of the century, the northern Olympic Peninsula was considered a "backward" area in the lumber manufacturing industry; its rugged environment and distance from markets made it unattractive to investors. Several sawmills, including one owned by the utopian Puget Sound Co-operative Colony, were constructed near Port Angeles and on the Elwha River in the 1870s and 1880s, and operated using waterpower (diversion dams and waterwheels). But these efforts lasted only a short time.[30]

In 1890, the City of Port Angeles boasted a population of 2,500 and granted an electric light franchise to the Washington Electric Light and Motor Company. The following year, the company provided the city with electric light for the first time, transmitting electricity to streetlights and residences from a steam-driven power plant which consisted of two incandescent dynamos, with a 600 light capacity, and one arc dynamo, with a forty light capacity. Though a modern convenience, the new system was expensive, and over the next several years, city leaders sought to decrease their lighting costs and augment their electrical supply. Municipal ownership and hydroelectric power seemed to offer the best solution. In 1892, the city unsuccessfully attempted to buy the Washington Electric Light and Motor Company's power plant and to build a 500 horsepower hydroelectric facility on Morse Creek. Municipal ownership advocates continued to press their case, and in 1893 the city voted to buy the electric plant and develop a small hydroelectric facility on the Little River, a tributary of the Elwha River. Neither venture materialized, however, most likely victims of the Panic of 1893.[31]

Interest in hydroelectricity continued unabated. It was in 1894, for example, that Aldwell and his friends turned an optimistic eye toward the future and the promise of power for a prosperous, industrial city. Two years later, Port Angeles community leader M.J. Carrigan amplified this optimism. He produced a booster pamphlet that rhapsodized about the unlimited possibilities of the region's rivers, once harnessed, to transform his city into the "Gate City of the Pacific Coast," complete with electricity for manufacturing, lighting, and streetcars, and electric railways for logging operations and pleasure outings to the surrounding lakes and coast. By the early 1900s, though, the best Port Angeles could boast was an electric lighting system operated by a seventy-five horsepower, steam-powered alternating current generator.[32]

Hydroelectric plants, however, were not built on dreams. They required large amounts of capital and to secure financial backing it was necessary to convince investors of the power project's soundness. Aldwell started down this road in 1908 when he entered into a new partnership with another Canadian, George A. Glines, a wealthy real estate operator from Winnipeg, Manitoba. Glines was an entrepreneur, it seems, who shared similar values as Aldwell. He invested in a great deal of property in Port Angeles, which led him to wonder about the future of a town "he considered," Aldwell wrote, "'an outpost of civilization.'" After learning of the Elwha power site, he purchased Brayne's interest for $30,000. In 1910, the two aspiring power developers formed the Olympic Power and Development Company. Aldwell and Glines selected a board of directors who represented "enterprise and integrity," provided they backed up these virtues with cash for their stock.[33]

The composition of the board's members suggested the power project's importance to the northern peninsula's industry. Members were drawn from the region's industrial and financial leaders involved in shipping, banking, law, and timber operations. Most of them were based in Seattle or the Port Angeles area. One board member, R.D. Merrill, however, was from Michigan. Merrill's presence indicated more than an outside investor's casual interest in a power project. Merrill was the principal owner of the Merrill and Ring Lumber Company, a firm that had become the dominant force in the northern Olympic

Peninsula at the turn of the century. He was part of what historian Robert Ficken has called the "Great Lakes connection." In 1900, another Great Lakes timber firm, the Weyerhauser Timber Company, made its mark in the Pacific Northwest when it purchased 900,000 acres of western Washington timberland from the Northern Pacific Railroad. Weyerhauser's purchase made it the second largest private timber company in the nation and the major player in the Northwest's forest industry. The purchase also set off a "turn-of-the-century rush to the Pacific Northwest," the company's "massive achievement." The rush attracted well-known investors and firms like Merrill and Ring to "backward areas like...the northern Olympic Peninsula," who in turn opened up the region with "timber and milling ventures." Thus, it was no coincidence that Merrill sat on the power company's board or that one of the main beneficiaries of the Elwha's power would be the wood products industry.[34]

The next step in the Elwha hydro project was to secure franchises and contracts for the proposed power development. Sometime in the early spring of 1910, the Olympic Power and Development Company requested a franchise from the City of Port Angeles, only to discover that Mayor F.S. Lewis, supported by Seattle investors, was proposing his own hydroelectric project on the Little River to supply the city with power. Lewis had been a major supporter of developing the Little River in the 1890s, and by 1910 it numbered among several proposals bandied about as power sites, including Ennis and Morse creeks. Aldwell, ever confident as he looked back over the decades in his autobiography, felt certain that he and Glines were well prepared to secure the franchise. They presented the city council with engineering reports, property ownership records, and the names of their influential board of directors, but still a bitter fight for the franchise ensued. Lewis vetoed the franchise ordinance passed by the city council. Although this kind of confrontation was not uncommon between rival power companies, especially between private and public utilities of the period, the local press claimed that the conflict was a dead issue; the Elwha project could meet the city's existing and future power needs many times over and do it more cheaply than the Little River project. "The proposition accepted," reported the Tribune Times,

> gives the city 25,000 kilowatt hours of service, from twice to three times as much as it is now getting, for exactly the same money. In addition to which it will afford an unlimited supply, from which the city may buy much or little, or all it may need at any time over and above that amount, at the low rate of from 2 to 2 1/2 cents per kilowatt hour, and this without any permanent investment for a plant or expensive maintenance of such. And this is about all there is to the deal.

In early April 1910, the city council overrode Lewis' veto and awarded the Olympic Power and Development Company the franchise. Afterwards, Glines and Aldwell secured contracts to sell their electricity to the Citizens Electric Company of Port Townsend and the Western Steel Corporation of Irondale, and arrived at tentative agreements with the federal government to supply the Bremerton Navy Yard and forts Worden and Flagler, both near Port Townsend.[35]

Buoyed by their success in securing a franchise and markets for the Elwha project, Aldwell and Glines courted financiers in Chicago hoping they would invest the money needed to build the dam. Locating financial backing in the East was a common practice for early hydroelectric projects in the West. Aldwell and Glines called on Peabody, Houghteling and Company in June 1910. Glines failed to impress the firm's accountant, Edward M. Mills, but Aldwell plied him with information on the company and won him over with photographs of the canyon and the Elwha River. The Olympic Peninsula would soon command the interest of everyone, Aldwell told Mills, and the rain-and-glacier-fed river he saw in the photographs was the source of an abundant supply of hydroelectric power.[36]

Peabody, Houghteling agreed to finance the project after it received the endorsement and the report of its own private engineers, L.L. Summers and Company.[37] With financial backing secured, Aldwell and Glines formed the Olympic Power Company. Its articles of incorporation named Glines as president, and Aldwell as vice president and general manager. The company was capitalized at $2 million, and Aldwell and Glines received a majority of the shares in common stock. On October 1, 1910, the Chicago financial firm floated a bond issue for $750,000 to build the hydroelectric project. The estimated cost of the plant's construction was $450,000, with the remainder of the money earmarked for future construction. As part of the contract, Peabody, Houghteling held Aldwell and Glines' common stock--its voting power--until the plant had been constructed, and made them responsible for full payment of the bonds. The terms of the agreement represented a shrewd business deal by Peabody, Houghteling and Company; the firm assumed almost total control of the project, while the Olympic Power Company assumed most of the risk, an arrangement Aldwell would deeply regret over the next several years.[38]

Aldwell's sense of being powerless in his own business affairs mirrored the alienation many Americans felt in modern society as giant corporations and the rising ranks of experts controlled more and more of daily life, limiting in the process opportunities for the local entrepreneur.[39] Aldwell was not alone in this regard, for Daniel H. Gilman, an energetic entrepreneur from Seattle, encountered a variety of financial and engineering problems when he attempted to build a power plant on his property at Snoqualmie Falls in the 1890s.[40]

Aldwell confronted this reality first when Peabody, Houghteling, as part of its contract with the Olympic Power Company, selected its own engineering firm, L.L. Summers and Company, to design and construct the Elwha project. Aldwell later concluded that L.L. Summers was hired because the Chicago investment house knew the engineers and their work well, and that they would be "better and cheaper" than anyone he could select. Aldwell also noted that there were some shady reasons for hiring the firm. One reason was that the company's finances were insecure and the Elwha contract would help them pay off debts owed to Peabody, Houghteling.[41]

In the end, L.L. Summers failed to construct a sound dam, perhaps proving Aldwell's suspicions that the engineering firm lacked in technical and managerial capability, and thus was responsible for the project's delays and cost overruns. Yet despite its troubles, the engineering firm wielded more influence with the Chicago investment house than Aldwell, all of which demonstrated that the history of the Elwha hydro project involved more than matters of technology. It also highlighted the influence corporations and experts exerted over ordinary Americans, especially in a society coming to terms with increasingly complex technology. Aldwell simply lacked the training and clout in the corporate boardroom to make his case that the engineering firm was doing a substandard job.[42]

In planning for the Elwha, L.L. Summers and Company proposed a design that was fairly typical of the era's hydro power developments in the West. The company called for a low-head, concrete gravity dam, 100' high, that would plug the narrow canyon. The dam's abutments would join it to the shoulders of the canyon, and a deep cutoff wall would seal off the base. The other features of the design included two multiple-buttress spillways and intake sections, six penstocks, and a powerhouse built about 200' below the dam containing two turbines and generators capable of producing 10,000 horsepower.[43]

As it turned out, all aspects of the power plant's construction proceeded normally, except for the dam's substructure. According to Aldwell, the cutoff wall, or foundation, of the dam was supposed to reach bedrock, but since the original plans do not exist, it is difficult to assess what the original design called for, especially since Aldwell's account dominates the history of the project.[44] Nevertheless, the issue of the dam's substructure emerged as the most controversial and critical aspect of the hydro project when construction commenced around August 1910.

In the early stages of planning and preparing the power site for construction, Aldwell continually expressed his anxiety over the dam's design to the Chicago investment house and engineers, but he was helpless to change it. Aldwell voiced the greatest concern over the safety of the dam's foundation. Though he had no technical training, Aldwell insisted on questioning Summers' design decisions. For example, Aldwell thought a tunnel rather than a wooden flume would have been a better method to divert the stream around the dam site, once the upstream and downstream coffer dams were built. In response, L.L. Summers defended his firm's design and instructed Aldwell in what was considered standard for this type of work. Aldwell, Summers indicated, was meddling in areas of expertise he knew nothing about and was causing more trouble than good. "It is quite evident to me," the engineer asserted, "that you have failed to grasp the fundamental basis on which this work is being executed." He informed Aldwell that a flume was a more economical and practical feature than a tunnel for constructing the dam. Both a flume and a tunnel faced similar risks in case of a flood and a dam breach. A flume then was the best choice because you could lose several flumes before reaching the cost of one tunnel. Summers staked his professional reputation on this issue, and angrily told Aldwell to "stop and think" before making such rash statements. "In this way, you will often see the fallacy of your arguments," he concluded.[45]

Unfortunately, Summers' firm was never able to demonstrate its professional abilities either to Aldwell or the engineering world. The company encountered numerous problems in construction that delayed the targeted completion date of October 1911 and pushed the hydro project's completion well into 1912. A variety of reasons, in Aldwell's opinion, were responsible. Summers' company failed to understand the natural conditions of the Elwha site; it improperly managed the project from afar, though it had a resident staff, and it used inefficient equipment and construction methods. As a result, progress was slow and held up even longer by accidents. While contractors normally bid on jobs and absorbed cost overruns, the Elwha situation was different. Under its contract with L.L. Summers and Company, the power company agreed to pay the firm a fee of 10 percent of the total cost of design and construction. Moreover, the agreement did not specify a completion date, but it was understood, Aldwell noted, that the work would proceed "with reasonable dispatch." The power company stood to lose money because it was under a deadline to deliver power to Port Angeles on April 15, 1912, a deadline the engineering firm assured Aldwell's company that it would meet. This arrangement was not only a major source of Aldwell's obsession--some might say interference--with the project's development, but also the reason he was forced to seek more funding for it since the slow-paced construction depleted the Olympic Power Company's funds.[46]

Ultimately, construction problems could be traced to the foundation. The engineering firm had selected a dam site that contained deep deposits of coarse and glacial till. Moreover, Summers never tested the depth of this permeable material that filled the narrow river channel. Because Summers' design called for hanging the dam between the walls of the gorge and building a deep cutoff wall beneath it, work crews excavated a few feet of this material with clam shell dredges and made no attempt to find bedrock. Still, the flume leaked and the porous riverbed let water seep between the coffer dams to such a degree that the water's depth never dropped below twenty feet. Unable to dry out the riverbed to pour concrete for the cutoff wall, the contractors resorted to pouring it "in the wet," employing the more primitive form of buckets instead of chutes. This, Aldwell exclaimed, stood out as one of the most improper and wasteful construction methods used. Workers threw "cement into the bottom of the river by the thousands of barrels in place of putting in a caisson. Had a good seasoned construction man been here, this would never have been done without testing the bottom of the river," he noted.[47]

Personally lacking technical expertise, Aldwell hired his own engineers to analyze the conditions at the dam site. They, in turn, helped shape his opinions. Fred Mandau, one of Aldwell's trusted engineers whom he placed on the construction project, informed him of the engineering company's practices. In Mandau's opinion, the dam would never hold back water once its gates were closed because the reservoir would seep underneath the foundation.

Eventually recognizing this problem, the engineering company constructed a caisson, a rectangular opening, at the center of the dam which was nearly as wide as the base of the dam itself. By the turn of the century, installing steel and concrete caissons offered an alternative to huge excavations for dam foundations with significant overburden.[48] The company intended to sink cutoff walls of reinforced concrete down to an impervious rock layer to prevent any more seepage beneath the dam. This approach seemed successful until a leak was discovered on the dam's downstream toe. After crews placed several thousand bags of sand and gravel on either side of the dam to plug the leak--though without success--they began excavating the caisson only to discover that the dam's cement foundation had nearly dissolved. It was now early summer 1912. The power plant should have been up and running, a fact that Aldwell pointed out in his letter-writing campaign to Peabody, Houghteling and Company.[49]

By now the relationship between Aldwell and the L.L. Summers and Company had deteriorated like the foundation of the dam itself. Aldwell had already tried to terminate the company's contract in April, and given this new situation, he marshalled even more evidence. He informed Peabody, Houghteling, for example, that the foundation problems resulted from the engineers' failure to excavate deep enough, and that the original bed of the river was 62' above sea level not 80' as claimed by the engineering company. By now Aldwell cited his own expert studies to support his claim that unless proper steps were taken the dam's safety could be jeopardized. Usually his words fell on deaf ears, but this time company president Alexander Smith shared Aldwell's contempt, telling him that "I am very disgusted with the delay in the completion of the plant." To assess the situation, Smith's company dispatched N.A. Carle, a consulting engineer, to inspect the cutoff-wall construction in June 1912. Carle essentially confirmed Aldwell's assertions that the dam practically rested on the streambed itself and should have been lowered to about 60'. While the dam was not in danger of failing in an ordinary flood, he warned that unless the cutoff wall was lowered a "blowout" would likely occur under the dam once the reservoir was raised to full height.[50]

Until Carle's report reached Peabody, Houghteling's offices, the financial firm sided with its engineering company. Anxious to raise the water behind the dam, the Chicago capitalists scrutinized Summers and Company's figures and plans, which indicated that the "natural bed" (or bedrock) of the river had been reached and the dam was safely sunk some 15' below this level. Summers' reports assured Peabody, Houghteling that the section of dissolved foundation had been repaired by installing a reinforced truss across the width of the canyon, which was firmly anchored in the canyon walls. The truss ensured the dam's safety--especially since the dam itself was wedged between the narrow canyon walls--and justified raising the water and generating electricity. (As of this time, the rest of the power plant had been constructed--penstocks, powerhouse, and transmission lines. See appendix for more detailed histories.) However much Peabody, Houghteling wanted to produce power and profits, it also did not want to destroy its investment or risk a law suit. When Aldwell protested raising the head for safety reasons, the firm reconsidered its position, but only after reading Carle's report. Afterwards, J.L. Houghteling, Jr., informed Aldwell that he was right about the riverbed level and that "we have been completely misled on that point."[51]

Summers himself finally admitted to Peabody, Houghteling that Aldwell was correct about the river bottom. Even so, the issue remained alive and confusion reigned. No one seemed sure just how deep it was to bedrock because no one had adequately tested the depth to solid rock. Assumptions rather than facts characterized this part of the project. In the early stages of construction, Summers struck large boulders at 70' when putting in the coffer dams and, it seems, assumed that a solid surface had been reached. Even after the flume and sluiceway had washed away a large hole in the riverbed below the dam, the riverbed only reached a level of 65', all of which led the engineering firm to believe it was building on solid ground. By not testing the depth of the fill beneath the dam, however, the firm failed to understand that the riverbed was changing. Gravel disturbed during construction, for example, flowed downstream raising the level of the riverbed directly under the dam; in fact, Carle noted, the upstream side of the dam "has been constructed on material filled into the river" since construction began. The 60' level which Aldwell promoted was itself only an approximate level of the riverbed and not solid rock. Shortly after confessing, Summers had his workers extend the cutoff wall down to 59' only to discover that workers could punch a bar 8' below this elevation. Engineers then concluded that it might be another 40' to bedrock.[52]

It was N.A. Carle who cut through the confusion and helped steer the project back on course. Prior to returning for another inspection, the engineer learned of this situation and refused to visit, stating in August that "this structure certainly will not be safe against blowouts underneath until such a time as the core wall goes down...into solid rock or some other satisfactory impervious material." He also clearly distanced himself from any liability for the project, for he had neither been consulted nor made any recommendations for the structure except that the water should not be permitted to rise behind the dam. Based on mounting evidence and expert testimony, Peabody, Houghteling fired its trusted engineering firm and placed the Olympic Power Company in charge of the project in late August.[53]

Aldwell and his power company may have won a round in their battle with outside experts but they still had to contend with an unfinished dam. The company continued to work on the dam's foundation over the next few months, attempting to reach a solid layer of rock. Work crews excavated downward to 49', and the company constructed a curtain wall of steel pilings across the canyon, a short distance in front of the toe of the dam. Pilings 50' long were then driven down below the surface; however, they still did not touch bedrock. By the middle of October, these modifications seemed to be working, and Peabody, Houghteling voiced its desire again to raise the water. To appease an ever apprehensive Aldwell, the firm retained another Midwestern engineer, Charles V. Seastone, of Mead and Seastone, to inspect the dam. While Aldwell was in Chicago negotiating with Peabody, Houghteling over this issue, the Elwha flooded, and the site manager allowed the head to rise behind the dam, apparently confident that the foundation would hold.[54]

In late October 1912, Seastone inspected the Elwha project with Aldwell, and the men observed water was flowing over the north spillway with hardly any leakage into the caisson. In fact, Aldwell noted that he "never saw [the dam] more favorable, and it was particularly pleasing that there was no more evidence of seepage with the full head on." Other components of the power plant, the electrical generating equipment, for example, tested positively. Seastone, who reviewed original plans and recent inspection reports, stated that he was "well pleased with the conditions as he saw them," and the current methods to strengthen the foundation.[55]

On October 29, 1912, Aldwell optimistically reported that the hydro plant was finally ready to produce power. He informed Port Angeles that the Elwha plant's electricity would arrive in November, and began courting new industry and a railroad to the region. The next evening, however, Aldwell sent a different message. Water was seeping under the sheet piling, weakening the piles and the cutoff wall. Suddenly, under the pressure of the full head of water, the dam's bottom blew out sending a torrent of water downstream and scouring the river bed to a depth of 80'. In what was probably the shortest letter of his voluminous correspondence with Peabody, Houghteling, he wrote: "Water went under dam. Lake gone out. Power House and machinery badly damaged."[56]

The entire reservoir of 12,000 acre feet passed through the gaping hole in the bottom half of the dam in one-and-a-half hours, carrying away the steel curtain wall and the caisson curtain walls. The flood overwhelmed the powerhouse and raged down the valley, sweeping away a county bridge and destroying other property in its path. No people were harmed since farmers downstream were warned in time. Debris and logs, which had caused a jam near the dam before the blow out, choked the canyon. Afterwards, its foundation gone, the dam spanned the canyon like a massive concrete arch. Also intact were the spillways, headworks, penstocks, gate mechanism, most of the powerhouse, transmission equipment and transformers. The flood destroyed the switchboard inside the powerhouse, and slightly damaged the turbines, generator, exciter, and governors.[57]

Despite advances in dam design and construction by the turn of the century, failures such as the Elwha continued to plague the engineering community.[58] While engineers did not knowingly set out to build inferior structures, they sought to learn from the failures of dams, buildings, and other engineering works. In 1895, the Bouzey Dam's failure in France, for example, focused attention on shear stresses, but the curved gravity dam was built on sand and gravel, noted Norman Smith, and "was undoubtedly weakened by its poor foundations." For this reason, Smith suggested, "the need to build dams on solid rock foundations" was also emphasized.[59] What interested the engineering press about the Elwha project was not its standard design but the dam's failure and reconstruction, which, according to the Journal of Electricity, Power and Gas, demonstrated a "gross neglect" of dam foundations and "utter failure to take adequate precautions against undermining."[60]

As the Engineering News reported, the foundation failure "was of an unusual character and the restoration of the foundation presented special problems due to the limitations of cost in order that the investment might still be retained on a paying basis." In other words, the Olympic Power Company and its financial backer, Peabody, Houghteling, could not afford an expensive solution to their problem; the original estimate of $450,000 to build the power plant was now around $1 million and climbing, and thus a simple, effective, and economical plan was necessary.[61]

In 1913, the power company retained Daniel W. Mead and Charles V. Seastone, well-known consulting engineers from Madison, Wisconsin, to design a new foundation. The firm's familiarity with the project made it a logical choice for the design, and Aldwell immediately scrambled to refinance for the anticipated repair work. The owners of the hydro project at first considered building a new dam for less expense than repairing the original. But test borings of the underlying strata above and below the dam failed to locate an adequate site, while borings near the dam located bedrock some 70' below the base of the dam. Moreover, other consulting engineers submitted proposals for closing and sealing the hole under the dam. One proposed method was to lower the base of the dam to bedrock using pneumatic caissons, a proven but expensive procedure at a cost of $600,000, substantially more than the $150,000 Mead and Seastone's plan estimated.[62] Ironically, the Mead and Seastone plan eliminated lowering the foundation to bedrock. Rather, the principle that the engineers employed was far more simplistic; they would block the opening with heavy rock fill above and below the dam, using various methods to keep the fill in place, a solution similar to those employed for "hydraulic works [diversion weirs and open dams] founded on a loose porous foundation of sand, gravel, or boulders."[63]

The first step in this process was to build five rows of interlocking steel pilings across the width of the canyon, two above and three below the dam. The steel curtains above the dam were spaced 15' and 95' from the dam; and the those below the dam were placed 10', 70', and 150' from the base of the dam, respectively. Driven down until their tops were flush with the streambed, the pilings helped decrease the subsurface flow of water without altering the river's flow.[64]

The next step involved building a rectangular caisson of steel sheeting between the first two rows of pilings below the dam (beginning about 25' from the dam's base). Its purpose was to allow for the construction of a concrete block to hold the rock fill, the idea for which came from James O. Heyworth, the Chicago contractor retained to carry out the repairs. Crews dug out some 30' of river gravel and sand and deposited concrete within the steel caisson, in "the wet" by means of bottom-drop buckets. This method allowed Heyworth's workers to pour the concrete from the riverbed up to the dam while losing little concrete in the still water. When finished, the concrete toe weighed some 3,000 tons.[65]

"The essential feature of the reconstruction," according to the chief construction engineer, Victor H. Reineking, "was the depositing of rock fill below the dam and the rock and earth fill above." Put another way, the hole had to be plugged and sealed. Engineers accomplished this task by carefully blasting the canyon walls above and below the dam. This turned out to be a rather complicated task since the blasts and the tons of rock sent flying from the explosions came as close as 10' from the dam. To avoid damaging the structure, crews drilled a series of deep holes and tunnels for explosives and blasted in a sequence--simultaneously firing off smaller charges and then heavier charges. The theory behind this approach suggested that the smaller charges would "cushion...the severe shock to the concrete dam" when the heavier charges were fired. It was also important that the blasts be fired simultaneously so that the fill would distribute and settle evenly in the riverbed, some 50,000 cubic yards of material. Although the firing did not go as planned, Reineking called the effort a success and noted that the dam was not visibly damaged.[66]

Several days after the blasting, the water level rose behind the dam and flowed over the north spillway, but there was still a considerable amount of seepage through the fill. The company's engineers then employed another inexpensive method to stop the seepage. They built large mats of Douglas fir to cover the river bottom on the upstream face of the dam and sunk them with rock ballasts. They also covered the mats and rock fill with soil, gravel, and other materials by means of dump cars and hydraulic sluicing operations. This work continued throughout 1914.[67]

Meanwhile, the power company made other modifications to the power facility in connection with the reconstruction. Most improvements related to increasing the spillway capacity in order to withstand various flood conditions within the Elwha watershed. Seastone determined that it "was impracticable" to do so "by extending the north spillway into the north bank," because this would require a massive retaining wall to hold up the north bank and create "a very awkward and inconvenient layout for the bridge across the dam." Instead he concluded that "the best and most economical method of increasing the spillway capacity would be to put in 20' tainter gates on both the north and south spillway, leaving the opening in the dams as they are." When installed, the steel tainter gates replaced the "primitive" stop logs, and increased the overflow capacity to about 50,000 cubic-feet-per-second.[68]

Seastone also noted that these modifications would require some structural changes, such as new piers on the north side of the dam to support the gates, and the "construction of a very substantial apron" on the south side of the dam. He did not see any way to "eliminate the south spillway for flood discharge." It was "perfectly practicable," he wrote, "to excavate a series of steps on the south bank in order to dissipate as much energy as may be possible from the water that will flow from the south side." Equally "practicable" was the fact that the rock from this excavation helped plug the hole in the dam, too, "thereby reducing the cost of the same." In the end, it was necessary to build a concrete retaining wall on the north bank of the north spillway to prevent the possible flooding of the powerhouse should the bank slide into the river, and thereby raise the water level.[69]

Flooding, an obvious concern given the history of the dam, influenced another design modification involving the powerhouse. The owners of the power company worried that the river channel below the powerhouse would inundate the lower floor of the building during floods. Seastone was unable to determine exactly how high the water would rise, but believed in the "most extreme cases" the river would reach the generator room floor. Thus, he recommended water-proofing the powerhouse's outside walls and the generator room floor to protect electrical equipment. To prevent water from entering over the bottom row of windows, he advised installing a steel shutter for each window's lower sash to make it water tight. (Eventually, workers sealed off the row of windows with concrete entirely. See appendices.) Concerned that log jams during floods would choke the channel and back water up into the powerhouse, Seastone recommended constructing as many as two booms to guide the debris through the tainter gates with relative ease and safety.[70]

By late 1913, the power company had completed most of the repairs to the power plant and was ready to go into operation. Though work to reduce seepage continued, the head was high enough to generate power. Thomas Aldwell certainly understood the importance of the reconstruction. As he watched the last blasts go off in November 1913, tears welled in his eyes, perhaps because he felt both vindicated and relieved after years of confrontation with the likes of Summers over construction of the dam.[71]

In January 1914, the Elwha River Powerhouse officially went on line, and it began transmitting power to Port Angeles and its other customers on the Olympic Peninsula. Two 3,000 kilovolt-amperes (kva) Westinghouse generators, driven by two Wellman Seaver Morgan-Francis type turbines, capable of operating under a 100' head and rated at 4,800 horsepower, were on line. Together the two units produced 9,600 horsepower. The two-story powerhouse also contained a direct current exciter unit of 200 kilowatt capacity, which also supplied power and lighting for the facility; a new switchboard, replacing the original damaged in the flood; and transmission equipment.[72]

After the Elwha project was completed, the engineering press both criticized and praised the work. Oran Jones, for example, indirectly blamed the engineering firm of L.L. Summers and Company for the dam's failure, specifically because it neglected "the principles governing the design of dams on porous foundations." The full effects of this neglect were felt well after the firm's dismissal, when the Olympic Power Company discovered its faulty data and inherited a flawed construction program. To the power company's credit, it hired the right engineers and contractor to repair the dam "efficiently and economically." What impressed Jones and his peers was that the reconstruction was both novel and feasible. Normally, engineers would have built the dam down to bedrock, but instead the original plan successfully repaired the dam foundation by methods that "adapted to the prevailing conditions" and differed "so radically from those usually employed in engineering operations of a similar character."[73]

In roughly a decade after it went into operation, the Elwha plant continued to undergo change, influenced by the increase in new markets and additional repairs to the hydro project after reconstruction, for despite pronouncements of success, the dam still leaked. In the fall of 1914, for example, Aldwell optimistically reported that the Elwha's power had in fact spurred the industrial growth he and his fellow boosters dreamed of some twenty years earlier. "The power market," he noted, "included light for Port Angeles, Port Townsend, Bremerton, and other small towns in the district; light and power for the U.S. Navy Yard at Bremerton; for a number of lumber mills, including a very large export mill at Port Angeles; for some canning plants; and for a number of smaller, scattered industries." As both a power producer and commercial promoter, Aldwell also helped influence the construction of a railway line to Port Angeles and the development of a shipyard. Similarly, he played a role, along with Peabody, Houghteling, in bringing the pulp and paper industry to Port Angeles over the next several years, which soon became the main consumer of the Elwha's power.[74]

The hydro project's ties to industry disguised the project's financial problems, many of which stemmed from the dam's construction and reconstruction. The years immediately after the Elwha facility's completion found Aldwell and Peabody, Houghteling working feverishly to sell power and the power plant itself to satisfy their creditors and bondholders. The Olympic Power Company negotiated the sale of the power plant to Seattle City Light in 1915 for $1.75 million (close to the cost, it seems, of building and rebuilding the dam), but the sale fell through for political reasons.[75] The following year, Peabody, Houghteling reorganized the company, and the Northwestern Power and Manufacturing Company purchased its assets. Finally, in 1919, the Zellerbach Paper Company opened the Washington Pulp and Paper Company in Port Angeles, which included a pulp mill and a newsprint mill, and as part of its new operations, acquired the Elwha hydro plant to power these mills.[76]

The paper company's purchase of the hydroelectric plant marked an important point in the project's history--the opening of the "pulp age" on the Olympic Peninsula. The industry expanded rapidly in western Washington after World War I mostly because of increased demands for paper, expanded markets, and the peninsula's abundant supplies of fresh water and relatively cheap hemlock. For these reasons mill developers were attracted to the rugged peninsula, and they needed power to operate their mills. Although Aldwell was active in drawing new industry to Port

Angeles to use the Elwha's power, Edward M. Mills was more influential. Mills was the junior partner with Peabody, Houghteling who was involved with the Elwha project from the beginning. During World War I, he came to Port Angeles to supervise the financially troubled power plant, and in doing so teamed with Isadore Zellerbach, head of the Zellerbach Paper Company in San Francisco, to launch the pulp and paper era on the peninsula. As part of his proposal, Mills sold Zellerbach on the idea of purchasing the power plant as "a nucleus of a new manufacturing venture at Port Angeles." The paper company executive was receptive to the offer because he wanted to secure a source of supply for his rapidly expanding business. Their first venture together a success, Mills and Zellerbach went on to develop a series of pulp and paper mills in Washington throughout the 1920s, helping to make Washington State a major pulp producer on the Pacific Coast.[77]

In the meantime, Aldwell, who held a management position with the Northwestern Power and Manufacturing Company, continued to try and repair leakage under the dam, which gradually increased over time. Attempts to increase the fill around the dam proved inadequate. More than an engineering problem, the dam's seepage was costing the company potential profits. As Aldwell noted early in 1918, it was imperative "to close the seepage" because demands for power were increasing which would push the plant beyond its current load capacity. In addition, the company needed to increase its water storage, for it was already "taking some chances" by signing contracts "without making provision for more water."[78]

Ironically, Aldwell stated that the seepage occurred as a result of blasting rock from the canyon walls to seal the blowout. What he meant exactly by this observation is not clear, except that approximately 160 to 200 feet-per-second-of-water was escaping from the reservoir behind the dam. Beginning in June 1918, the power company engaged in hydraulic sluicing operations to deposit more fill on the riverbed above the dam. Aldwell again retained the services of Victor Reineking, the engineer who oversaw the reconstruction and who suggested that the fill be extended farther up river from the dam--approximately 350-400'--to cover any breaks in the streambed. Even so, the sluicing did not slow the seepage enough, reducing it only some 40 percent.[79]

In 1919, Aldwell hired W.C. Morse, an engineer from the Puget Sound Bridge and Dredging Company in Seattle, Washington, to solve the problem. Morse, who had "constantly advised" Aldwell about his power plant, initially teamed up with another hydraulic engineer, D.C. Henny, from Portland, Oregon, to work on the project. Drawing on their experience with similar projects and up-to-date techniques for sealing seepage in reservoirs, Morse and Henny devised a plan that called for treating the area above the south spillway with a 3"-thick asphalt coating.[80] To install this asphalt coating, work crews drove a row of 10' metal sheet pilings from the dam along the outer edge of the asphalt to the south bank and covered the tops with the seal. They also extended the asphalt layer up the south bank as far as possible, plugging the bank above the seal with clay to make it impervious. This treatment significantly reduced the seepage in this section behind the dam.[81]

The power company then hired Morse to solve the leakage problem for the remaining area. To accomplish this, Morse spread a 3"-thick-layer of gunite over the rest of basin above the dam; the gunite was applied over support piles and was reinforced with a grid of steel bars. As part of this entire process, work teams constructed a series of coffer dams to allow for the repairs and for the power plant's continued operation; all of these were temporary, except for a midstream coffer dam which engineers left in place, covering its south side and top with reinforced gunite. Morse noted that other repairs were undertaken during the sealing operation. For instance, he and his workers discovered and repaired large holes in the bay floors of the south spillway's tainter gates. In the end, Aldwell reported, these repairs reduced the seepage by 92 percent.[82]

To the informed observer, the much-repaired Elwha dam seemed to be a patchwork of concrete, steel pilings and sheets, fill, and other materials used to coat, seal, or plug leaks. Engineering problems and financial realities drove these repairs. A sound dam meant more power, and more power meant more money. Soon after the Washington Pulp and Paper Company started its operations in the early 1920s, the existing powerhouse could not meet its load demands and was expanded. By 1922, an annex to the powerhouse was completed and two new generating units were added to supply the mill, the water capacity for these units increased by sealing the reservoir. These new units were vertical Seaver Morgan, Francis-type turbines, rated at 5,000 horsepower each, and they drove two Westinghouse alternating current generators, each rated at 3,330 kilowatts. A 15' in diameter penstock, with bifurcated ends, fed water to the turbines, the pressure of which was regulated by a surge tank located just above the powerhouse.[83] By the early 1920s, with its flaws repaired and its power generation expanded, the Elwha hydroelectric project seemed to have finally achieved the success its developers envisioned.

Developing Glines Canyon Dam: Part II of the Elwha River System

In the early 1920s, the Elwha River plant supplied power to several industries, as well as domestic and commercial users, throughout the northern peninsula, the Zellerbach Company's mill being one of its main consumers. As the power plant's developers had hoped, industry had grown and expanded, in part, as a result of this electric supply. In 1922, for example, Zellerbach added a second newsprint machine, the power for which was provided by the generating units in the Elwha powerhouse addition. By 1924, Zellerbach planned to expand still further and thus needed another source of power for its pulp mill in Port Angeles. Although the problems with the Elwha dam consumed much of the energy of Thomas Aldwell and his associates in the Olympic Power Company, they had plans to develop four power sites, including the plant in Aldwell Canyon, along the Elwha River--plans which were supported by hydraulic engineers working for both the federal government and private firms. Shortly after the completion of the Elwha power plant, Aldwell noted that the other potential power sites were McDonald Bridge, Rica Canyon, and Glines Canyon. He estimated that all of these combined could produce 267,000 horsepower, using a 40 percent load factor.[84]

Although power company officials looked seriously at the McDonald Bridge and Rica Canyon sites, they ultimately selected Glines Canyon for the construction of the second hydro plant. The attraction to Glines Canyon seems to have been for practical and technological reasons. The company owned the land on which the project would be built, thanks to the early real estate speculation carried out by Thomas Aldwell and George Glines. The land also remained in possession of the power companies which succeeded the Olympic Power Company--the Northwestern Power and Manufacturing Company (1916), the Northwestern Edison Company (July 1924), and finally the Northwestern Power and Light Company (August 1924), all of which were subsidiaries of Zellerbach. Throughout this reorganization and consolidation, Glines Canyon retained its importance to the power system's future. Consulting engineers as early as 1913, for example, observed that the canyon, located approximately seven miles south of the Elwha plant, presented an ideal spot to build a high-head dam. The narrow gorge was about 50' wide at the bottom and about 200' high. Its walls rose almost perpendicularly from the river, the bottom of which was rock, an important feature given the problems building the Elwha dam. A high-head dam in this canyon could generate about 34,000 additional horsepower.[85]

Equally important was the fact that power company officials believed they could build a dam at Glines Canyon rather efficiently and economically. A rock spur on the west side of the river offered a natural place to drive a diversion tunnel, which could later be used to convey water to the powerhouse. In addition, Charles Seastone noted that the company could construct a concrete arch-type dam, saving substantially on material costs; the company would also save money by installing large power generating equipment and running the plant in conjunction with the first facility at Aldwell Canyon. For these reasons, Seastone concluded, "a development can be made...from which power could be sold at a pretty low figure and at the same time yield good returns on the investment."[86]

Seastone's observations anticipated the Glines Canyon power station by more than a decade. By February 1925, the Northwestern Power and Light Company had selected Glines Canyon as the site for its next power development and hired the engineering firm of Thebo, Starr and Anderton from San Francisco, California, to prepare plans for the new project. Just as Peabody, Houghteling and Company had done, the Northwestern Power and Light Company selected reputable engineers from the same city as its head office. The power company's vice president, E.M. Mills, formerly with Peabody, Houghteling, did not feel comfortable using W.C. Morse as the new project's engineer.[87] Although Morse was valued for his work repairing the Elwha dam, Mills thought he lacked both the experience and expertise necessary to complete successfully the Glines Canyon project. The engineer's preliminary plans apparently displayed little sophistication. Morse proposed building a diversion dam about one mile downstream from the canyon and conveying water through a concrete ditch to the lower Elwha power plant.[88]

Thebo, Starr and Anderton, on the other hand, contemplated developing an arch dam and powerhouse at Glines Canyon. The firm's selection of an arch dam reflected a growing preference for this type of structure among the engineers in western states in the 1920s. This type of dam, though not entirely accepted by all engineers for safety reasons, was a popular choice for projects in the West, with its numerous, narrow mountain canyons and rugged, inaccessible places in which it was expensive to build. Arch dams, ideally suited for narrow canyons, thus offered an economical solution to the limitations imposed by the West's physical landscape; they also required less material than the more traditional gravity dams, which in turn enabled power developers to construct taller dams and impound more water.[89]

Final plans for the new power plant took shape between 1925 and 1926 as the project went through the permit and licensing process. During this time, the hydro project expanded in size. In March 1925, Northwestern Power and Light filed an application with the state for water rights at Glines Canyon. The approved permits authorized the appropriation of 600 cubic-feet-per-second and the storage of 20,000 acre feet of the Elwha River. Within a year, however, W.B. McMillan, the project's head engineer, requested and by May was granted additions to these permits, which raised the amount of appropriated water to 800-cubic-feet-per-second and doubled the amount of water for storage.[90]

McMillan offered no direct reason for this change, though the plans for the dam were not complete until they met the final approval of the Federal Power Commission. Although located on private land, the power project required a federal license because its reservoir would inundate land in a national forest (Olympic National Forest). Early in 1926, McMillan submitted the preliminary plans for the Glines Canyon project to the commission. Although McMillan admitted that there were no firm "specifications" for the Glines dam, it conformed to the basic principles of a variable-radius arch design, measuring approximately 55' across the base, 155' across the top, and 200' high. After reviewing the plans, the commission directed McMillan to modify the dam design to meet its "specifications as to allowable stresses and arch formulae."[91]

Critics of arch dams stressed that they were unsafe, thin concrete eggshells, while their proponents, such as Lars Jorgensen, the hydroelectric engineer who designed and patented the concept of the constant-angle arch dam, claimed that arch dams possessed a better safety record compared to other dam types.[92] To ensure the soundness of arch dams, the power commission adopted the theory developed by mathematician William Cain to determine the stresses at any given point in a dam. McMillan then revised the design of the Glines Canyon dam using Cain's formula:

> We have met the Federal Power Commissioners requirements for design, shaping the arch rings to conform to Professor Cain's theory and reinforcing the top to carry the thrust to the spillway crest. The maximum stresses are 360 pounds per square inch compression and 100 pounds per square inch tension, abutments fixed and accounting for shear. We are designing the concrete mix in contemplation of having at least 1,500 pounds per square inch in twenty seven days.[93]

Although a similar dam designed by Jorgensen for Seattle City Light's Diablo Canyon site became embroiled in political controversy and the debate over arch-dam safety around this same time, the Glines Canyon dam was spared these troubles; it was a private development removed, somewhat, from the struggles between public and private power interests, the source of the Seattle City Light issue. McMillan made his changes quickly, and the Federal Power Commission licensed the project in May 1926.[94]

Compared to the power plant in Aldwell Canyon, the construction of the Glines Canyon project was accomplished with relative ease, beginning in May 1926 and ending a year later. The steep canyon walls and the relatively remote location of the power site on the upper Elwha River no doubt created many engineering challenges for Thebo, Starr and Anderton, but nothing, it seems, the firm was not prepared for or which posed any insurmountable difficulties. Some of the more notable highlights featured the hydro project's construction in the remote and rugged terrain of Glines Canyon. To reach the canyon, construction teams completed a five-mile wagon road from the Olympic Highway through the soggy ground along the river. The road provided a lifeline for bringing in supplies and workers, and hauling in the project's heavy equipment.

Once at the construction site, engineers faced their toughest obstacle--the canyon itself. The deep and narrow gorge forced all construction buildings and equipment to be located on the embankments high above the river. Of all aspects of construction, the dam's completion exemplified best these rather perilous conditions. The concrete mixing plant, cement shed, and storage facilities were built as close as possible to the rim of the canyon. This allowed the pouring of concrete through a chute suspended from a cable across the canyon to fill forms some 70' below. Even more problematic, as McMillan observed, was the excavation for the abutment foundations, which "was difficult and precarious" due to the "narrowness of the gorge, and the overhanging rock walls." These conditions made it necessary "to excavate in stages as the concrete was carried up," and to delay the excavation of the side walls until the bottom concrete had been poured "in order that the gorge would not be choked with debris." Obtaining aggregate for the concrete also proved somewhat difficult. The sand had to be imported since the Elwha's finer gravel was of a poor quality. In addition, even though contractors mixed gravel from the riverbed below the powerhouse, saving on material costs, the quality of this course aggregate varied to the extent that the dam's concrete was tested by chemists and engineers in Seattle and San Francisco to assure it met the proper standards (2,000 pounds-per-square-inch compressive strength in 28 days).[95] Finally, unlike the Elwha project, building the foundation did not pose any problems; work crews built a diversion tunnel through the canyon wall to send water around the dam site, instead of a flume which was used for the Elwha dam.

The Glines Canyon power station was placed on line on April 29, 1927.[96] In its finished form, the Glines Canyon power plant displayed a simple elegance, combining both beauty and utility in its design. The single-arch dam, rising more than 200' above the river, conformed to the topography of the canyon walls. Where the east wall of the canyon widened considerably, engineers built a heavy concrete gravity abutment to anchor the upper section of the dam, and they built an auxiliary earthen dam extending east from the abutment. The spillway section contained five tainter gates, which were installed on the west end of the dam, and discharged from a concrete spillway apron. Water cascaded nearly 200' to the canyon floor without touching the precipitous rocky ledges of the canyon. Adjacent to the spillways, an unembellished concrete gatehouse was erected. And crowning the entire structure, a walkway, adorned with ornamental light standards, spanned the dam's crest.

The water conveyance system consisted of an intake and power tunnel, above which stood the concrete gatehouse, a pressure pipe, surge tank, and penstock, all of which carried water to the reinforced concrete powerhouse sited more than 800' downstream from the dam. Inside the powerhouse, a single, vertical shaft Francis type turbine, manufactured by the Pelton Water Wheel Company and rated at 17,500 horsepower under a 180' head, drove a General Electric vertical, alternating current generator rated at

13,333 kva with direct connected exciter. Located a short distance from the powerhouse, an outdoor transformer station, containing three General Electric 4,500 kva transformers, raised the voltage from 6,600 to 66,000 volts, which was then transmitted to the Elwha plant.[97]

This description of the power station, though brief, reflects the "defacto" standardization hydroelectric plant design underwent in the 1920s. By no means, according to Duncan Hay, were hydro plants standardized to the point of being interchangeable, given the different types of low and high head plants, their related equipment, and the characteristic styles associated with certain companies. Nevertheless, standardization resulted from a combination of "cumulative experience, national and regional technical periodicals, the growing influence of engineering and management firms, holding companies, and corporate consolidation."[98]

What perhaps set the Glines power station apart from others of its time was its semi-automatic and remote control system. Although engineers began to theorize about the possibilities of running hydroelectric plants without operators at least a decade before the Glines project, practical automatic control systems did not appear until the 1920s. At the time the Glines Canyon project was undertaken, control systems had advanced enough to allow "generators to start, come into synchronization, and go on line, as systems loads demanded or pond elevations warranted." Remote control helped operators monitor and control plant conditions and output, at first using telephone and later radio and microwave technologies, most of which were not fully developed until after World War II. The advantage of automatic and remote control technology was that it enabled the coordination of operations between plants on the same river to provide a more cost effective and well-regulated electric power system.[99]

Creating a power system of at least four interconnected power plants on the Elwha, after all, had been one of the driving forces behind the development at Glines Canyon. In fact, the power station's automatic and remote control capabilities formed one of its engineering highlights.[100] McMillan touted the Glines installation as "the largest automatically equipped single unit water wheel generator so far constructed," one that would be "operated from the Elwha station by means of a selector supervisory type of remote control." This system for the most part was controlled by means of an automatic switchboard, furnished by the General Electric Company; it allowed the Elwha plant attendants to start and stop the Glines generating equipment, vary its speed, raise or lower the generator's voltage, and control the load once the Glines plant was on line. The system, however, was not entirely automatic, because as a safety feature, the main butterfly valve had to be opened by hand in order for any of the other equipment to function. Broadly speaking, the automatic control system brought both plants into synchronization and achieved the speed regulation necessary for meeting the load demands of the paper mills which they primarily served. The automatic system and the need for speed regulation, to a certain degree, also dictated some of the power plant's design. The generator, for example, was specially designed with a "heavy flywheel effect," and a surge tank of the Johnson differential design was selected to equalize the pressure variation of water passing through the long pipeline from intake to powerhouse.[101]

If automation distinguished the Glines Canyon power station somewhat from other hydro projects of the time, the style of its dam did not. Arch dams, though criticized in some engineering circles, were quite popular by the 1920s. Lars Jorgensen in particular helped fuel this popularity. A native of Denmark, Jorgensen immigrated to the United States at the turn of the century and worked as a hydroelectric engineer in California. In 1914, he created his own consulting firm, the Constant Angle Arch Dam Company. The name of the firm referred to the type of arch dam Jorgensen first designed at Salmon Creek, Alaska, that same year, and subsequently patented. Arch dams were not new to the engineering world; several in the American West in the late nineteenth and early twentieth centuries demonstrated the capabilities of thin, high arch masonry dams.[102] These dam designs, however, employed a constant radius arch which, according to Jorgensen, meant that there was only one arch near the crest of the dam that was the precise shape for true arch action and stability. His constant angle concept, on the other hand, employed a variable radius through his drawing of precise arches for every contour level and then stacking them to construct a dam. Reportedly stronger and more economical to build than a constant radius dam, the constant angle arch concept produced some of the world's tallest variable-radius arch dams.[103]

By the late 1920s, two of these, Cushman No. 1 and Diablo Canyon Dam, had been erected or were under construction in western Washington using Jorgensen's design.[104] Both dams were owned by Tacoma and Seattle municipal utilities, respectively, and perhaps this close proximity and the press the Glines project received brought the work of Thebo, Starr and Anderton to the attention of Jorgensen's firm. For soon after the construction of the Glines Canyon Dam began in 1926, Jorgensen's Constant Angle Arch Dam Company warned Thebo, Starr and Anderton that it was infringing on two of Jorgensen's patent claims relating to the constant angle arch concept.

In response, W.B. McMillan asserted that he gave "no consideration of the constant angle principle" in his design of the Glines Canyon Dam. Rather, the dam was designed with the "general type of warped surface" that conformed to the canyon's "topographic features" and the Federal Power Commission's specifications for "allowable stresses and arch formulae" based on the Cain theory. All of these factors made Glines "a very special case." Moreover, McMillan aggressively suggested that most of Jorgensen's patents had been anticipated, citing as an example the Osmena Dam erected in the Philippine Islands by Major H.F. Cameron, and pointing to his own training as an engineer which antedated Jorgensen's claims. McMillan also advised the Northwestern Power and Light Company to resist the Constant Angle Dam Company's requests to inspect the dam's plans. McMillan's contentiousness emerged from his belief that the company would not file a patent infringement law suit, for Jorgensen had not previously enforced his patent claims, agreeing instead on royalty fees rather than pursuing costly litigation. The Constant Angle Arch Dam Company, however, would not be bullied, and on July 5, 1927, filed a patent infringement suit against the Northwestern Power and Light Company.[105]

Faced with the suit, McMillan maintained his original stance, although he conceded that the Glines Dam did not differ from Jorgensen's patent for an arch dam as far as "general conformation." He tried to strengthen his position by explaining that his dam design differed specifically because it was customized to fit into the canyon and to meet the Cain theory, all of which affected the "resulting thickness and angles subtended by the arch rings" rather than a "simple ring formula." Jorgensen's lawyers countered that, despite McMillan's claims of uniqueness, his contention was really "based on some theory that the Jorgensen patents are not valid." This reasoning, the company's lawyers stated, "does not worry us" because of the precedent set by similar contracts and cases. Both the City of Los Angeles and the City of Seattle, for example, signed royalty contracts with Jorgensen's company for dams they were building using the constant angle arch design. The most damming evidence, however, concerned earlier work of Thebo, Starr and Anderton in which the firm had infringed on the Jorgensen patents when it built the Kerchoff Dam for the San Joaquin Light and Power Company: an investigation in this case resulted in San Joaquin Light and Power Company agreeing to pay a royalty fee in order to avoid a law suit. To settle its suit, Jorgensen's company required a fee based on 4 percent of the dam's construction cost, a sum that would "scarcely pay either side the expense of litigation," but necessary for Jorgensen "to assert his rights to prevent widespread and general disregard of his patents and to protect his licensees." Apparently, the Northwestern Power and Light Company and its lawyers believed that "the accomplishments of the Jorgensen patents" would most likely "outweigh any theoretical defenses in the eyes of the Court," and on January 3, 1928, settled out of court with the Constant Angle Dam Company.[106]

After Glines Canyon: The Elwha River Hydroelectric System

Though the flap over the design of Glines Canyon Dam subsided, it spoke to the fact that the Elwha hydroelectric system was associated with the growth of large electrical power networks throughout the United States in the 1920s and early 1930s. As Thomas Hughes has shown, a fully developed electrical system contained a series of individual parts unified by a single network. A power network, Hughes contends, acts like other technological systems, evolving through four phases: invention followed by introduction into the market place, and then from "system growth" to rapid growth or full integration within society. When the Glines Canyon power station went on line in the late 1920s, for example, the Elwha power system was no longer an isolated facility, but part of a growing, regional power network.[107]

Located on the remote Olympic Peninsula, the Elwha power system adequately supplied the area's small centers of population and industry during its early years of operation and remained separate from the larger urban-industrial networks across the state. Yet the Elwha system's success in spurring the peninsula's economic and industrial expansion led to its eventual integration into a larger power network in the late 1920s. Together the Elwha and Glines power plants produced approximately 25,000 KW of power, which supplied the electricity and power to the major cities and industries of the northern peninsula. Even with the addition of the Glines Canyon plant, the Elwha system soon could not meet its load demands, especially those of its main customer, the Washington Pulp and Paper Corporation in Port Angeles, which supplemented the Elwha power with its own steam-driven power plant during low water periods.[108]

Aware of opportunities in the peninsula's market, one of Washington's large power companies, the Puget Sound Power and Light Company, began to consolidate the peninsula's power output into a single system while the Glines facility was still under construction. In 1926, it purchased most of the Northwestern Power and Light Company's distribution system and substations; it also purchased Port Townsend's system. Two years later, Puget Power purchased the Silverdale Light and Power Company, and in 1930 acquired the last suburban distribution system near Port Angeles. Soon after, Puget Power's power plants transmitted electricity across the Puget Sound, supplying its new customers including Port Angeles, one of the Elwha system's original consumers. Yet Puget Power was still unable to provide enough power. During this period, for example, Crown Zellerbach--Zellerbach merged in 1928 with Crown Willamette Paper Company--furnished its new kraft paper mill with power from several steam turbines, as did another pulp mill owned by the Olympic Forest Products Company, which began operating in 1930 and is today's Rayonier Incorporated. To solve the growing demands of industrial, residential, and commercial users, all of the groups involved formed a "power pool."[109]

The demands for increased power and the advent of the power pool curtailed plans to develop the entire Elwha power system. By September 1927, the Northwest Power and Light was no longer a public utility, since it had sold off most of its transmission network, and retained only power distribution lines with the Port Angeles mills. Moreover, it abandoned plans to build two more power stations on the upper Elwha, and in 1937 Crown Zellerbach acquired the title to both power plants from its subsidiaries, (Northwestern Power and Light Company and Washington Pulp and Paper Company).[110]

Another and more important factor limited the Elwha power system's future development--a radical change in the design of hydroelectric power stations. During the Depression, the federal government assumed a greater role in American society than ever before. One aspect of this was the federal government's promotion of hydroelectricity, shifting the focus away from private utilities--whose managers had scaled back or postponed most of their hydro plans because of the crippled economy--toward a renewed interest in public power. Franklin Roosevelt's New Deal programs funded the majority of hydroelectric projects undertaken in the 1930s, such as those erected or initiated in connection with the Tennessee Valley Authority and the Columbia River Basin. These projects created enormous multiple-purpose dams, such as Grand Coulee, the world's largest concrete dam located on the Columbia, that were capable of generating and transmitting power on a vast regional scale.[111]

By 1949, the full effects of this were witnessed on the Olympic Peninsula when hydroelectricity from the Columbia River power system--Bonneville and Grand Coulee dams--reached Port Angeles and surrounding Clallam County. Crown Zellerbach played a significant role in tapping into the Bonneville Power Administration's supply to augment its own hydroelectric plants on the Elwha. It was at this point, finally, that the Elwha power plants were fully incorporated into a regional system and their role in that process was as solid as the concrete dams holding back the river.[112]

Capitalism, Power, and Fish: The Legacy of the Elwha Hydroelectric System

In 1940, an aging Thomas Aldwell wrote long-time business associate Edward M. Mills informing him that the reservoirs behind the Elwha and Glines Canyon dams had been named Lake Aldwell and Lake Mills, respectively, in their honor. Aldwell took the moment to reflect upon the Elwha system, telling Mills he could not help but think of "what small events change the course of our lives and careers," as well as the "development and changes of Districts and even Countries." Mills worked for the

Chicago firm that financed the first Elwha dam and though he initially expressed no interest in the project, he changed his mind after seeing pictures of the wild Elwha basin. "So owing to your being a lover of nature," Aldwell penned, "and willing to look at the photos and listen to my chatter was the small event that has resulted in the creating and naming of Lakes Mills and Aldwell." Aldwell, and Mills in particular, lured the pulp and paper industry to Port Angeles with the hydroelectric power plant on the Elwha, all of which, in Aldwell's mind, was ultimately responsible for that city's industrial success.[113]

Aldwell's perspective on nature, as something to appreciate and develop for profit, was that of a capitalist, and thus from a contemporary perspective the paradox that seems inherent in his views may not have been so clear to him or to those of his time. As environmental historian Donald Worster as recently noted, the control of water in the American West was driven by our modern capitalist culture in which water has "no intrinsic value, no integrity that must be respected." The inspirational beauty of a river flowing through a narrow canyon evaporated when it became "a commodity that [was] bought and sold and carried to the marketplace." For Aldwell and his like-minded contemporaries, a pristine watershed like the Elwha was transformed into purely a commercial abstraction, "so many 'kilowatt-hours' of generating capacity to be spent," its features described in a "new language of market calculation" that asserted an "ultimate power over nature...a domination that is absolute, total, and free from all restraint."[114]

Although Worster's focus was on the control of water in the arid West for irrigation, his interpretation offers a valuable framework for understanding the far-reaching effects of the Elwha River Hydroelectric System. Besides remaking nature to produce electricity for the Olympic Peninsula, the project disrupted the river's ecosystem, nearly destroyed the river's native anadromous salmon and trout runs, dramatically reduced the treaty fisheries of four federally recognized Indian tribes, and blocked their access to many traditional fishing and culturally important sites on the river. While these topics are beyond the scope of this study and are covered elsewhere in greater detail, they point out that the Elwha dams were not designed with fish in mind.[115] Capitalism, after all, valued the ability of science and technology to devise "ways to extract from every river whatever cash it can produce." In the case of the Elwha, hydroelectricity rather than fish promised to bring unlimited abundance to the project's owners and to society at large. The reasoning behind this approach was a kind of "rationalized irrationality," a perspective employed in business which considered making money the most important goal without examining its ends, whether that be the depletion of ancient forests, the exhaustion of fertile soil, or the extermination of entire species.[116]

By the early 1890s, natural scientists and conservationists recognized that dams obstructed anadromous fish runs and thus eliminated them from the reservoirs they created. Fishery laws required that dam owners construct fishways or passages so fish could pass above the dams, if they naturally ascended past the sites of these structures, yet cases abounded where the laws were ignored or compliance with them was only partial.[117] Although Washington State enacted a similar law in 1893, it was evidently disregarded in the original design of the Elwha Dam. It was not overlooked, it seems, because fishways or fishladders had never been constructed at dams, but rather because they were too costly--that is, to build as well as maintain, especially given the dam's height of some 100'.[118]

Throughout the years the dam was under construction, negotiations between Aldwell's Olympic Power Company and the State Fish Commission, though shrouded in some secrecy, demonstrated that the combined influence of powerful financial interests, politicians, and the promise of hydroelectric power could reduce the value of wild salmon to a matter of economics.[119] As with many conservation issues of the time, the debate touched upon one of the most fundamental characteristics of American society--the opportunities for individuals to enrich themselves from the country's natural wealth with as little government regulation as possible. In fact, conservation policies during the early decades of this century aimed to make resource use more efficient rather than prevent individuals from using nature's bounty.[120]

In the end, this combination of forces enabled the power company to build a hatchery just below the dam in place of a fishway. (Olympic Power Company would donate the land and contribute $2,500 towards its construction.) At first Aldwell resisted this compromise, most likely given the fact that the dam and its reconstruction had depleted his company's finances. But later, in August 1914, he agreed to the proposal, but only after confronted with growing criticism over the loss of fish from fishermen and canneries below the dam and the increasing impatience of the state fish commissioner, Leslie Darwin, who threatened to enforce the fishway law if the power company did not comply. Darwin's deal sidestepped the law and the Elwha Dam was technically illegal and could have been removed. Yet he crafted this solution because of his faith in science to propagate salmon artificially in the hatchery below the dam and his desire that another run of salmon would "not beat its brains out against the dam." His solution was also aided by Governor Ernest Lister, who moved in similar circles as Aldwell and was intrigued by hydroelectric power, and managed to have the law revised so that hatcheries could be built in lieu of fish passageways soon after.[121] The hatchery, however, failed by 1922 and was abandoned. With only a few salmon ascending the Elwha to the base of the dam and no salmon runs above the structure, construction of fish passage facilities at Glines Canyon Dam was all but a moot point in 1926.[122] Various attempts proposed or implemented in the ensuing decades could not recover the lost runs of the Elwha, testimony to the legacy of power production and the control of one river in the West.

The Elwha River Hydroelectric System: Its Past and Present Significance

Rivers mark the passage of time. The power stations on the Elwha River mark eras in the river's history, just as they mark eras of hydroelectric power plant design. On the lower section of the river stands the Elwha plant. Built between 1910 and 1914, it belongs to a period before World War I, an era as, Duncan Hay has noted, when power plant design was considered to be innovative and experimental, with some plants becoming the "darlings of the engineering press" while others slipped into "relative obscurity" soon after they went on line.[123] The Elwha station seems to have experienced the latter. It attracted the engineering world's attention because of the blowout of its dam's foundation and successful repair, but nothing about its design pushed the limits of engineering technology. It was and remains a representative example of a low-head hydroelectric installation in Washington State from the early twentieth century. A few changes have been made to the system over the past sixty years, yet it retains most of its original character.[124]

More important than mere physical artifacts is the link the Elwha plant had to Thomas Aldwell and his entrepreneurial vision of city building that was so characteristic of his era. Aldwell's efforts to develop a hydroelectric power plant on the Elwha saw him enter a world controlled more by the rising ranks of experts and corporations, a reality he resisted, but, as the evolution of the power plant and the company which developed it illustrates, it was a reality to which he eventually succumbed.

One other notable feature of the Elwha's hydroelectric structures emerged with the completion of the Glines Canyon project in 1927: the use of a variable-radius arch dam and its semi-automatic, remote control generating system. Yet, however noteworthy, these attributes placed the Glines Canyon installation strictly within the mainstream of power plant design, the "defacto" standardization which characterized the 1920s and early 1930s. Moreover, although Glines Canyon boasted one of the state's last dams erected specifically for power generation, thus marking the end of an era in Washington State's early hydroelectric development, by the 1930s and 1940s, regional power networks and large multiple-purpose dams came on line and eclipsed the role of local systems like the one on the Elwha River.[125]

Though the Elwha River hydroelectric system slipped into "relative obscurity," it continued to supply power to Port

Angeles industry. Yet in order to comply with federal regulations it was forced to revisit its past. Beginning in the late 1960s and mid 1970s, Crown Zellerbach attempted to license its Elwha power plant for the first time (1968) and to relicense its Glines Canyon station (1976). The licensing process set off a complex chain of events involving federal regulations and public protest, in particular from the S'Klallam Tribe of the lower Elwha, against the presence of the dams. Although federal regulations touched upon issues of dam safety, for example, both federal concerns--as represented by the Federal Energy and Regulatory Commission--and public concerns focused on the river's nearly depleted fisheries. The fact that the expansion of Olympic National Park in 1940 included the Glines Canyon hydro property further stoked public outcry against the presence of the dams and their disruption of natural systems. The licensing dispute has continued for some twenty years, involving the James River Corporation, the most recent owners of the Elwha power plants, and Daishowa America, the current owners of the Port Angeles pulp mills formerly owned by Crown Zellerbach. The dispute culminated in 1992 with a federal law directing the Department of the Interior to determine the best way to restore the Elwha River's ecosystem and fisheries, with numerous provisions, the main ones being the acquisition and removal of the Elwha River dams by the federal government--a course of action that was determined by the Secretary of the Interior in 1994.[126]

ENDNOTES

1. The above is drawn from Oran D. Jones, "The Olympic Power Company's System," Journal of Electricity, Power and Gas 35 (October 9, 1915): 279-280; Robbin B. Sotir and Associates, "Preliminary Findings Report, Elwha River Ecosystem Restoration, Olympic National Park, Washington," October 6, 1994.

2. Gail Evans, Historic Resource Study: Olympic National Park (Seattle: National Park Service, 1983), 5-12.

3. Evans, Historic Resource Study, 12-51.

4. Ibid., 12-23. Robert L. Wood, Across the Olympic Mountains: The Press Expedition, 1889-1890 (Seattle: University of Washington Press, 1967), 42-57, especially 46-47.

5. Evans, 48-50, 225-244, 281-289. Quotation from 202.

6. Ibid., 61-65, 76-87.

7. Ibid., 76-87.

8. Ibid., 126.

9. Thomas T. Aldwell, Conquering the Last Frontier (Seattle: Superior Publishing Company, 1950), viii. (Forward by George Savage)

10. Aldwell, Conquering the Last Frontier, 3-18. Quotations from 5, 17, 18.

11. Paul J. Martin, Port Angeles, Washington: A History, vol. 1 (Port Angeles: Peninsula Publishing Company, 1983), 23. Cited in Fringer, Olympic National Park, 11.

12. Aldwell, 19-20.

13. Ibid., 21-30. Quotation from 26.

14. Ibid., 68.

15. Ibid.

16. Ibid., 68-69. Peter J. Schmitt, Back to Nature: The Arcadian Myth in America (New York: Oxford University Press, 1969).

17. Aldwell, 70, 79-80.

18. Ibid., 79-80.

19. Ibid., 70, 80-82. Untitled newspaper clipping, September 16, 1898, in Thomas T. Aldwell Scrapbooks, Special Collections, University of Washington. Port Angeles Tribune-Times, February 11, 1910.

20. Thomas P. Hughes, Networks of Power: Electrification in Western Society, 1880-1930 (Baltimore: Johns Hopkins University Press, 1983), 2.

21. Duncan Hay, Hydroelectric Development in the United States, 1880-1940 (Washington, D.C.: Edison Electric Institute, 1991), 1-12.

22. Hay, Hydroelectric Development in the United States, 13-25, 27-32. Lisa Soderberg, "Hydroelectric Power Plants in Washington State, 1890-1938," (National Register of Historic Places Multiple Property Documentation Form, 1988), E1-E3.

23. Richard White, The Organic Machine (New York: Hill and Wang, 1995), 49. Electric power companies were still heavily promoting the Northwest's hydroelectric power potential in the mid-1920s. See O.B. Coldwell, "Hydroelectric Power in the Pacific Northwest," Journal of Electricity 56 (January 1, 1926): 8-9.

24. Soderberg, "Hydroelectric Power Plants in Washington State," E1-E12.

25. Hay, Hydroelectric Development in the United States, 28-32. Soderberg, "Hydroelectric Power Plants in Washington State," E3.

26. Soderberg. Carlos Schwantes, The Pacific Northwest: An Interpretive History (Lincoln: University of Nebraska Press, 1989), 190-199.

27. Soderberg, E14. Roger Sale, Seattle, Past to Present (Seattle: University of Washington Press, 1976), 70-77. Robert M. Fogelson, The Fragmented Metropolis: Los Angeles, 1850-1930 (1967; reprint, Berkeley: University of California Press, 1993), 229-246, presents a good account of the municipal reform movement in one of the West's most important cities.

28. Nancy Farm Mannikko, "Skagit Power Development: Skagit River and Newhalem Creek Hydroelectric Projects," United States Department of the Interior, Historic American Engineering Record (HAER), No. WA-24, June 1990, Prints and Photographs Division, Library of Congress, Washington, D.C., 3-6. Soderberg, E-17. Wesley Arden Dick, "Visions of Abundance: the Public Power Crusade in the Pacific Northwest in the Era of J.D. Ross and the

New Deal," Ph.d. dissertation, University of Washington, 1973.

29. Richard White, "It's Your Misfortune and None of My Own": A History of the American West (Norman: University of Oklahoma Press, 1991), 395, 416-417, 423-425. See also Earl S. Pomeroy, The Pacific Slope (Seattle: University of Washington Press, 1973), and William Cronon, Nature's Metropolis: Chicago and The Great West (New York: W.W. Norton and Company, 1991).

30. Robert E. Ficken, The Forested Land: A History of Lumbering in Western Washington (Seattle: University of Washington Press, 1987), 100-101. See also, Crown Zellerbach Corporation, 1890-1949: More Power to You...Port Angeles and Clallam County, pamphlet, ca. 1949.

31. Crown Zellerbach, More Power to You. See also, The Port Angeles Tribune, February 19, 1891, reprinted in the above citation. While the early history of Port Angeles' lighting is outlined in this publication, a detailed and scholarly account is not available.

32. Carrigan's pamphlet is cited in Martin, Port Angeles, Washington, 83, and reproduced in a photocopy format as "Port Angeles: The Gate City of the Pacific Coast," ca. 1896, copy on file at Olympic National Park. The power plant's description can be found in More Power to You and The Port Angeles Tribune-Times, April 8, 1910.

33. Thomas Aldwell, Conquering the Last Frontier, 71, 82-83. Quotation from 82.

34. Aldwell, 82-83. Robert Ficken, The Forested Land, 91, 100-101. Quotations from 100.

35. Ibid., 83-84. Wesley Arden Dick, "Visions of Abundance"; Gregory Gray Fitzsimons, "The Perils of Public Works Engineering: The Early Development of Utilities in Seattle, Washington, 1890-1912," Master's thesis, University of Washington, 1992, 82-85, 195-197. The Port Angeles Tribune Times, April 8, 1910. The franchise date is unclear--More Power to You cites April 5, and Aldwell cites April 8.

36. Aldwell, 86. The photographs also included images of Lake Sutherland and Lake Crescent.

37. Aldwell uses the fictive name of L. Sullivan and Company.

38. Ibid., 87-90.

39. Robert H. Wiebe, The Search for Order, 1877-1920 (New York: Hill and Wang, 1967), 45-46, 164-195.

40. Gregory Fitzsimons, "The Perils of Public Works Engineering," 163.

41. Aldwell, Conquering the Last Frontier, 91-92, 105.

42. Wiebe, The Search for Order; Brian Balogh, "Reorganizing the Organizational Synthesis: Federal Professional Relations in Modern America," Studies in American Political Development 5 (Spring 1991): 119-172.

43. The original plans may still be extant but their whereabouts are unknown. Two accounts of the power plant's design can be found in Oran D. Jones, "Olympic Power Company's System," Journal of Electricity, Power and Gas 35 (October 16, 1915): 297, and Aldwell, 92-93. See also Oran D. Jones, "Olympic Power Company's System," 35 (October 9, 1915): 280, for original plan descriptions. Aldwell's recollection seems flawed. He states that each generating unit could produce 10,000 horsepower.

44. The reader should be aware that Aldwell's biography is the only known full-length treatment of the Elwha Dam. The biography, though biased, can be compared with and analyzed against his personal papers housed at the University of Washington. Aldwell's papers paint a more balanced picture of his involvement in the project, but one should be skeptical when Aldwell ventures outside his understanding of basic engineering. No matter these issues, the fact that the L.L. Summers firm failed to build a good dam lends some credence to Aldwell's criticism.

45. L.L. Summers to Thomas T. Aldwell, October 8, 1910, box 1, file 37, Thomas T. Aldwell Papers, University of Washington Libraries. This file contains other letters about early construction and design matters.

46. See Aldwell's twenty-two page report, Thomas T. Aldwell to E. Mills, April 18, 1912, box 2, file 16, Aldwell Papers. In other areas of the project's history, the nature of the accidents seemed fairly typical for this kind of construction. One worker lost his footing on a scaffolding high above the river and fell to his death. Two others died when they were swept into the river after a cable broke on a derrick. This latter accident received a fair amount of press because the owner of a local paper was injured as well.

47. Jones, "Olympic Power Company's System," 35 (October 16, 1915): 297-298; Thomas T. Aldwell to L.L. Summers, November 7, 1911 in Aldwell to Mills, April 18, 1912.

48. Nicholas J. Schnitter, A History of Dams: The Useful Pyramids (Brookfield: A.A. Balkema, 1994): 211.

49. Jones, 298; Thomas T. Aldwell to Alexander Smith, June 10, 1912, box 2, file 18, Aldwell Papers.

50. Alexander Smith to Thomas T. Aldwell, June 4, 1912, box 1, file 24; Smith to Aldwell, June 28, 1912, ibid; N.A. Carle to E.M. Mills, July 16, 1912, box 1, file 5, Aldwell Papers.

51. J.L. Houghteling, Jr. to Thomas T. Aldwell, July 2, 1912; J.L. Houghteling, Jr. to Thomas T. Aldwell, July 12, 1912; J.L. Houghteling, Jr. to Thomas T. Aldwell, July 27, 1912, box 1, file 24, Aldwell Papers.

52. J.L. Houghteling, Jr., to Thomas T. Aldwell, July 2, 1912; N.A. Carle to E.M. Mills, July 16, 1912. N.A. Carle to Thomas T. Aldwell, August 16, 1912, box 1, file 5, Aldwell Papers.

53. N.A. Carle to Aldwell, August 16, 1912. Aldwell recounts, in a somewhat confusing way, the same story in Conquering the Last Frontier, 104-105.

54. Jones, 298. It is possible that construction matters influenced this decision, since the flow of the river through the sluice ways was interfering with pile driving operations.

55. Thomas T. Aldwell to Peabody, Houghteling and Company, October 25, 1912, box 2, file 21, Aldwell Papers.

56. Thomas T. Aldwell to Peabody, Houghteling and Company, October 29, 1912; Thomas T. Aldwell to Peabody, Houghteling and Company, October 30, 1912, ibid. It should be noted that Aldwell states in his autobiography that the date of the blow out was October 31. It is clear from Aldwell's own correspondence and various articles such as the one by Jones, "The Olympic Power Company's System," (October 16, 1915), that the blow out occurred on the 30th.

57. Port Angeles Olympic Leader, November 1, 1912; Jones, 298.

58. Lars Jorgensen, "Record of 100 Dam Failures," Journal of Electricity 44 (March 15, 1920): 274-276. Note this issue is only the first part of Jorgensen's compilation up to 1918.

59. Norman Smith, A History of Dams (London: Peter Davies, 1971), 204-205.

60. Jones, 301.

61. "Reconstructing the Foundation of the Elwha River Dam," Engineering News 70 (December 18, 1913): 1258. Aldwell, Conquering the Last Frontier, 108-110.

62. In 1908, the United Missouri River Power Company built a dam, measuring 70' in height and 630' in length, across the Missouri River. Both ends were founded on bedrock but its center--a steel dam--was not; it was built on water-bearing gravel and the river undermined the dam's substructure. In 1911, the company completed repairs, building a new dam clear down to bedrock--a difficult process--using diversion dams, a flume and pneumatic caissons to reach bedrock some 60' below the river. See "Difficult Deep Foundation Work at the Hauserlake Dam, Montana," Engineering News 65 (June 22, 1911): 743-747; Terry S. Reynolds, "A Narrow Window of Opportunity: The Rise and Fall of the Fixed Steel Dam," IA: The Journal of the Society for Industrial Archeology 15 (1989): 1-20.

63. "Reconstructing the Foundation of the Elwha River Dam." More detailed coverage of the reconstruction can be found in the article written by the engineer in charge of the construction work, Victor H. Reineking, "Reconstruction of the Elwha River Dam," Engineering Record 69 (March 28, 1914): 372-375. Charles V. Seastone's ideas for the reconstruction can be found in a trip report he prepared, Memorandum Port Angeles Trip--C.V. Seastone, ca. July 1913, box 3, file 18, Aldwell Papers. Another valuable report is one commissioned by George Glines; see R. Hayward to George A. Glines, December 23, 1914, box 2, file 6, Aldwell Papers. The method employed here was similar to those outlined in "Dams, Barrages and Weirs on Porous Foundations," Engineering News (December 29, 1910): 708-710, an article which concentrated mostly on dams much lower than the Elwha, yet the same principles seem to apply to the Elwha project.

64. The pilings never reached bedrock. According to recent river surveys, the solid rock below the dam is found at around 0' to 20' above sea level. See United States Army Corps of Engineers, Elwha River Basin, Elwha Dam, Port Angeles, Washington, Phase 1 Inspection Report National Dam Safety Program, (August 1978).

65. Measurements vary about the spacing of the steel curtains. These figures are drawn from Reineking, "Reconstruction of the Elwha River Dam," 372-373. See also "Reconstructing the Foundation of the Elwha River Dam," 1258. Heyworth's credit can

be found in Alexander Smith to Thomas T. Aldwell, April 23, 1913, box 1, file 26, Aldwell Papers.

66. Reineking, 374. The explosives were to have gone off simultaneously, but the timing faltered and they fired off separately, though close enough together to achieve the goals of the engineers.

67. Jones, 300-301; Reineking, 374-375. See also, Thomas T. Aldwell to E.M. Mills, November 17, 1913, box 2, file 24, Aldwell Papers.

68. Memorandum Port Angeles Trip--C.V. Seastone, ca. July 1913, box 3, file 18, Aldwell Papers. Jones, 299.

69. Seastone memorandum. Thomas T. Aldwell to E.M. Mills, September 18, 1913, box 2, file 23, Aldwell Papers.

70. Seastone memorandum.

71. Aldwell, 111-112.

72. Jones, "The Olympic Power Company's System," (October 9, 1915); Aldwell to Mills, November 17, 1913. Original plans called for six penstocks--four for generators and two for exciters, and the intake structure was built with six headgates. See appendices.

73. Jones, 301. See also the inspection report by R. Hayward, consulting engineer from the Western Canada Power Company, whom George Glines hired to inspect the repair work; R. Hayward to George A. Glines, December 23, 1914, box 2, file 6, Aldwell Papers.

74. Aldwell, 117, 125-130. Aldwell's papers contain more detailed information on his role in attracting industry to Port Angeles, in particular the Washington Pulp and Paper Corporation and the Zellerbach Company. See, for example, Thomas T. Aldwell to Alexander Smith, August 8, 1916, box 2, file 29, Aldwell Papers. But as noted in the text below, Edward M. Mills played a larger role than Aldwell in opening the pulp and paper industry in the region.

75. Aldwell, 118. There may have been other reasons complicating the sale, which Aldwell does not disclose, and which further inspection of his papers and those of Seattle City Light may reveal. For a sense of the hydro project's financial problems and need for markets, see E.M. Mills to Thomas T. Aldwell, January 18, 1917, box 1, file 30, Aldwell Papers.

76. More Power to You. Ficken, 173.

77. Ficken, 172-174. Quotation from 173.

78. Thomas T. Aldwell to V.H. Reineking, January 8, 1918; Thomas T. Aldwell to E.M. Mills, February 21, 1918, box 2, file 39, Aldwell Papers. Quotation from Aldwell to Mills. For a sense of revenues being lost, see this file for an undated, second page of a letter from Aldwell to Mills.

79. Thomas T. Aldwell to E.M. Mills, October 3, 1918, box 3, folder 2. See also letters in box 2, file 39.

80. D.C. Henny helped solve seepage problems at the Cedar River Dam, owned by the City of Seattle. W.C. Morse provided him with technical advice. See "Blanket Versus Cut-Off Wall for Sealing Bank at Cedar River Dam," Engineering Record 71 (May 22, 1915): 656-657.

81. Aldwell, 113. Aldwell recounts the repairs in greater detail in his rough drafts for his autobiography rather than in his published book. See box 3, file 19, Aldwell Papers. W.C. Morse to Thomas T. Aldwell, November 11, 1919, box 1, file 33, Aldwell Papers. Morse was quite proud of the asphalt material, noting it withstood extreme temperatures well and was practically water tight. See above citation.

82. Ibid.

83. Johnson, "Draft: Historical Assessment of the Elwha River Fisheries," 32; Crown Zellerbach, More Power to You.

84. Thomas T. Aldwell to Howard D. Hughes, September 23, 1915, box 2, file 28, Aldwell Papers.

85. The evolution of the Olympic Power Company into the Northwestern Power and Light Company is recounted briefly in Johnson, 52. Soderberg describes the evolution of power companies in Washington State, "Hydroelectric Power Plants in Washington State," E4-E6. For a national context, see Thomas P. Hughes, Networks of Power, 366. In addition to the surveys of federal agencies, the power company officials who oversaw the Elwha projects relied on the reports of two consulting engineers, C.V. Seastone and R. Hayward. Seastone made his observations in a trip report from the summer of 1913, Memorandum Port Angeles Trip--C.V. Seastone, ca. July 1913, box 3, file 18, Aldwell Papers. Hayward made his observations in his report to George Glines in 1914; R. Hayward to George A. Glines, December 23, 1914, box 2, file 6, Aldwell Papers.

86. Hayward and Seastone reports.

87. According to Mannikko, 15, Morse was City Engineer for Seattle in June 1927.

88. E.M. Mills to J.C. Higgins, February 19, 1925, box 32, file 6; A.M. Torpen to Donworth, Todd, and Higgins, February 18, 1925, box 30, file 14, Frank E. Holman Papers, University of Washington Libraries. The power company applied for and received a preliminary permit from the Federal Power Commission in 1924 for the diversion dam and ditch project proposed by Morse. See Torpen to Donworth, Todd and Higgins, February 18, 1925, and "Preliminary Permit Granted for Elwha River Power Site," Journal of Electricity 55 (December 15, 1924): 457.

89. See Mannikko, 11-12, for discussion of arch dams.

90. Torpen to Donworth, Todd and Higgins, February 18, 1925; W.B. McMillan to Donworth, Todd and Higgins, February 8, 1926, box 30, file 14; W.B. McMillan to Donworth, Todd and Higgins, May 27, 1926, box 32, file 9, Holman Papers. One account notes that the original figure for storage was 15,000 acre feet. See W.B. McMillan to Donworth, Todd, Higgins and Holman, April 14, 1926, box 32, file 9, Holman Papers.

91. W.B. McMillan to Donworth, Todd and Higgins, February 8, 1926; W.B. McMillan to Major H.F. Cameron, September 10, 1926, box 30, file 14, Holman Papers. Quotation from McMillan to Cameron. W.B. McMillan to Donworth, Todd, Higgins, and Holman, April 24, 1926, box 32, file 9, Holman Papers.

92. Lars Jorgensen, "Arch Dam Design: The Constant-Angle Arch Dam," 68 (July 25, 1912): 155-157.

93. W.B. McMillan to R.K. Tiffany, May 19, 1926, box 32, file 9, Holman Papers. Cain developed his theory at a time when knowledge had recently increased about how to calculate the compressive strength of concrete and thus approach dam design more scientifically. He criticized the cylinder theory used by engineers to calculate the thickness of dams. See Mannikko, 17.

94. W.B. McMillan to R.K. Tiffany, June 16, 1926, box 32, file 9, Holman Papers. See Mannikko, "Skagit Power Development," 11-19.

95. W.B. McMillan, "The Glines Canyon Hydro-Electric Development on the Elwha River of the Northwestern Power and Light Company, Port Angeles, Washington, Western Construction News 2 (April 10, 1927): 33-38.

96. "Automatic Hydro Plant Put in Operation," Engineering News 99 (July 21, 1927): 118.

97. W.B. McMillan, "The Glines Canyon Hydro-Electric Development," 34-37.

98. Hay, Hydroelectric Development in the United States, 95-96. The other dams, as noted in the above text, were Cushman No. 1 and Diablo dams.

99. Hay, 121-122. Frank V. Smith, "Automatic and Supervisory Control of Hydro-Electric Stations," Power 64 (July 13, 1926): 67-68.

100. One article in the engineering press, for instance, called the Glines plant "the largest single-unit automatic hydroelectric generating station in this country, and probably the world." See, "Largest Single-Unit Automatic Hydro-Electric Station," Power 64 (November 23, 1926): 773.

101. McMillan, "The Glines Canyon Hydro-Electric Development," 33, 35; "Glines Plant Under Supervisory Control," Electrical West 60 (April 1, 1928): 196-198.

102. These were the Sweetwater Dam in Southern California (1888), and the Pathfinder and Buffalo Bill dams in Wyoming (1905-1910). See Schnitter, A History of Dams, 197-199.

103. Schnitter, 199-201; see table of world record variable-radius dams, 201. Jorgensen, "Arch Dam Design," 156. For biographical material and an insightful analysis of Jorgensen's work on a particular project, see Nancy Farm Mannikko, "Skagit Power Development," 12-19.

104. Mannikko, and J.V. Gongwer, "The Cushman Hydroelectric Development," Electrical West 58 (March 1927): 129-133.

105. W.B. McMillan to Major H.F. Cameron, September 10, 1926; W.B. McMillan to D.C. Henny, September 10, 1926, box 30, file 14; W.B. McMillan to Northwestern Power and Light Company, March 9, 1927, box 30, file 11; W.B. McMillan to E.M. Mills, September 13, 1927, box 30, file 14, Holman Papers.

106. W.B. McMillan to Donworth, Todd and Holman, November 19, 1927; Charles E. Townsend to Zellerbach Paper Company, November 26, 1927, box 30, file 14, Holman Papers. For the patent suit decision, see box 32, file 5, Holman Papers. This file contains most of the information on the suit itself, yet it seems to be missing the final settlement information.

107. Thomas Hughes, Networks of Power, 6-9, 14-15, cited in Fitzsimons, 146-147. See also Soderberg, "Hydroelectric Power Plants in Washington State, E5-E6, E13.

108. Crown Zellerbach, More Power to You.

109. Ibid. Crown Zellerbach Corporation, Partners in Industry, pamphlet, ca. 1930s, 5. Rayonier Incorporated was the result of three mills on the peninsula merging in 1937. The pulp mills, including the one at Port Angeles, produced Rayonier, a special pulp used in the manufacture of rayon, one part of the forest products industry that managed to prosper during the Depression. It is interesting to note that Edward M. Mills, who three plants merged to form Rayonier Incorporated, was directly responsible for this success by forming an alliance with the rapidly expanding rayon industry. See Ficken, The Forested Land, 173-174, 184-185, 216.

110. Zellerbach Paper Company purchased the Washington Pulp and Paper Corporation and the Elwha power plant in 1919, but it did not operate it directly, allowing other affiliated companies, such as the Northwestern Power and Light Company, to take care of the daily business. In 1934, the Glines Canyon installation was sold or transferred to the Washington Pulp and Paper Corporation before being formally taken over by Crown Zellerbach in 1937. The National Register Nomination for the Elwha and Glines Canyon hydroelectric projects does not give a reference for the sale of these power plants, yet indicates they were both purchased by Crown Zellerbach in 1937, though it indirectly owned them. What seems clear is that no matter the corporate changes, by 1937 the power plants were dedicated to produce power for the pulp and paper mills owned by Crown Zellerbach. Also noteworthy is that 1937 was the year that the complex merger between Zellerbach Paper Company and Crown Willamette Paper Company was finalized. See Ficken, 174.

111. Soderberg, National Register Nomination, 8-2. Hay, Hydroelectric Developments in the United States, 123-132. White, The Organic Machine, 65.

112. Crown Zellerbach, More Power to You; Thomas Aldwell, Conquering the Last Frontier, 139-140. Bonneville Dam came on line in 1938 and Grand Coulee Dam in 1941; White, 72.

113. Thomas T. Aldwell to E.M. Mills, March 31, 1940, box 3, file 15, Aldwell Papers.

114. Donald Worster, Rivers of Empire: Water, Aridity, and the Growth of the American West (New York: Pantheon Books, 1985), 52.

115. See, for example, Department of the Interior, The Elwha Report: Restoration of the Elwha River Ecosystem and Native Anadromous Fisheries (January 1994). This published report covers the specific issues related to the Elwha hydroelectric system's impact on the river's ecosystem and native cultures.

116. Worster, Rivers of Empire, 52, 55. The final quoted phrase is quoted in Worster, 55, and is from the work of Max Horkheimer. Other historians of conservation and environmental history point out, however, that emphasizing America's capitalist culture tends to simplify our relationship with nature by overlooking broader themes related to society, ecology, and culture. See, for example, Arthur F. McEvoy, The Fisherman's Problem: Ecology and Law in the California Fisheries, 1850-1980 (New York: Cambridge University Press, 1986).

117. A.M. Spangler, "The Decrease of Food-Fishes in American Waters and Some of the Causes," Bulletin of the United States Fish Commission 13 (Washington, D.C.: Government Printing Office, 1893), 21, 23-24.

118. Charles W. Maib, "A Historical Note on the Elwha River: Its Power Development and Its Industrial Diversion," prepared for the State Department of Fisheries, ca. 1952, photocopy in author's possession.

119. Presumably, there was concern for sea-run trout as well, but the literature seems to focus more on salmon.

120. Bruce Brown, Mountain in the Clouds: A Search for the Wild Salmon (New York: Simon and Schuster, 1982), 61-74. Samuel P. Hays, Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890-1920 (Cambridge: Harvard University Press, 1959).

121. Charles W. Maib, "A Historical Note on the Elwha River," 6-21; Darwin is quoted in Bruce Brown, Mountain in the Clouds, 71.

122. Maib, 24-25. In a letter written to the Northwestern Power and Light Company's law firm in 1926, E.M. Mills noted that the law for fishways existed and that it would most likely arise in the case of the Glines Canyon project. But given the precedent set by the lower Elwha dam, it was not likely that anything of consequence would arise. See E.M. Mills to Donworth, Todd, and Higgins, March 29, 1926, box 30, file 11, Holman Papers.

123. Hay, 27-28.

124. These assessments are drawn primarily from Lisa Soderberg's National Register Nominations for the Elwha Hydroelectric Project and the Glines Canyon Hydroelectric Project.

125. Ibid.

126. This summary is drawn from the Department of the Interior, The Elwha Report, xi-xii. For a detailed and comprehensive discussion of the licensing and fisheries dispute, see Philip Johnson, "Draft: Historical Assessment of the Elwha Fisheries," 128-160.

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Appendix:
Historic Structures of the Elwha River Hydroelectric System

HEADWORKS: ELWHA HYDROELECTRIC PROJECT

Elwha Dam

The Elwha Dam is a concrete gravity dam with a multiple-buttress spillway and intake sections. The dam measures approximately 100' in height, although original plans called for extending it to about 120'. (On the stepped face of the downstream elevation of the dam rows of rebar projected from the concrete for future additions. These can be seen in historic photographs.) At its base, the dam measures about 40' in length and at its crest about 122'. Including the spillways and intakes, the top of the dam measures 417' in length. The dam also contains six overflow bays, five of which are about 17' wide and one of which is about 12' wide. A one-lane road spanned the crest, connecting the housing for power plant workers with the main road. Wedged into the narrow canyon, the dam is built firmly between the canyon shoulders, and in plan the dam tapers at its middle and widens where it adjoins the canyon walls.

The dam was designed originally by L.L. Summers and Company, an engineering firm from Chicago, Illinois, for the Olympic Power Company in 1910. Construction began that year, but was slowed by numerous construction problems and design issues related to the base of the dam, primarily seepage under the cutoff wall. The entire structure was nearly completed in October 1912 and the power plant ready to come on line when the foundation washed out on October 30. A new engineering firm was hired to repair the damage and finish the dam. Daniel W. Mead and Charles V. Seastone, well-known consulting engineers from Madison, Wisconsin, undertook the project and devised an inexpensive and original method to block the hole with rocks, fill, and a massive concrete toe. Although various efforts to stop seepage under the dam would continue for years, Mead and Seastone completed the dam by 1914, and in January that year, the Elwha power plant went on line.

Spillways and Headgates

The Elwha dam has two multiple-buttress spillways on its north and south sides. The north spillway section measures 82' x 8" in length and contains four spillway bays; the south spillway measures 90' x 10'-1/2" in length and contains five spillway bays. During repairs to the dam, engineers extended the north spillway to the north bank and contained its channel between two massive concrete retaining walls. At the same time, they installed steel tainter gates measuring 13'-9" x 23'-0" in each spillway bay, replacing the more primitive stop logs originally used. The new tainter gates, according to Charles V. Seastone, would help increase the overflow capacity. In connection with installing the tainter gates, structural changes to the dam were made, such as the installation of new piers on the dam's north side to support the gates. The tainter gates were "of the latest pattern," noted an engineer in 1915, and were commonly used in early twentieth-century American power stations. The gates were originally designed to be raised either manually or from the switchboard by means of cables connected to motor-operated hoists mounted on rails.

The headgates are part of the intake structure built in the buttressed section of the dam next to the north spillway and regulate the flow of water to the penstocks. Six headgates were built originally because plans called for installing a total of six penstocks. (When the dam was completed in 1914, though, only three penstocks had been installed.) Two headgates measure 12' x 15' and a smaller gate measure 5' x 8'. The remaining headgates had similar dimensions because they were to be used for two generator penstocks and one exciter penstock. A hydraulic hoist operated the gates. In addition, trash racks were installed in front of the gates to prevent debris from entering into the turbines.

It should also be noted that around 1919 a concrete diversion block was built in front of the intake structure to divert water. The reason for this structure is unclear, but historic photographs show it being constructed around the same time work crews were sealing the reservoir. One of the coffer dams used in that sealing operation was left intact and covered with concrete. It runs perpendicular into the diversion block.

Penstocks and Surge Tank

As originally designed, the project contained six penstocks, four for generators and two for exciters. Three were installed by the time the plant went on line in 1914. These were two 9'-6" in diameter steel penstocks connected to the larger headgates, and a 30" in diameter exciter penstock attached to the smaller headgate. All of these measure 190' in length. In 1921 and 1922, the Northwestern Power and Light Company added two more large penstocks. These branch from the headgates and join with a 15'-diameter penstock. This passes through a riveted-steel surge tank just above the entrance to the powerhouse annex, where it branches again before entering the structure.

Powerhouse

The Elwha powerhouse is a simple, concrete structure measuring 90' x 70' and is structurally supported by reinforced concrete columns between which extend curtain walls. The structure rests on bedrock some 200' below the dam; its foundation consists of concrete piers connected by reinforced concrete beams that measure 16' in length. The powerhouse is 60' high, has two stories, and contains steel-framed glass windows. The lower floor contains the generating units, switchboard, and other equipment, such as a Whiting crane with a 30-ton hoist and its associated crane runway, which traverses the building's length. The upper floor contains the transformers and high tension switching equipment.

Construction of the powerhouse began in 1910. It was completed and installed with generating equipment and ready to go on line in October 1912. The dam's blowout on October 30 flooded the powerhouse and severely damaged the structure, slightly damaged the turbines, generators, exciter, and governors, and destroyed the switchboard. Needless to say, concerns about flooding influenced the repairs the Olympic Power Company made to the building. To keep the river from damaging the lower levels of the powerhouse in case of floods, work crews waterproofed the outside walls and floor of the generator room, including the generator pits. Charles Seastone also recommended installing a steel shutter in the lower sash of each window in the bottom row of the powerhouse to guard against high water seeping into the building. "With this precaution," he wrote in July 1913, "I feel confident that no trouble will be experienced by virtue of the rise in water below the power house." It is unknown whether these shutters were put into powerhouse windows, but most likely engineers discovered that the water level rose well above the bottom row of windows and to remedy this problem, they walled up the lower section of windows with concrete. (See historic photos and powerhouse HAER drawings.) Other repairs to the powerhouse included reinforcing the generator pits by adding 18" of concrete to the original 6". By November 1913, these and other repairs to the powerhouse and generating equipment had been completed, new equipment had been installed, and the powerhouse was once again ready for operation.

The powerhouse contains two Wellman Seaver Morgan-Francis type, double-runner turbines. Operating under a head of 100', each turbine was rated at 4,800 horsepower when installed. Each turbine is directly connected to a 3,000 kva Westinghouse alternators of the revolving field type, which generated three-phase current at 6,000 volts, when operating at 360 revolutions per minute. Lombard governors of the oil pressure type regulated and controlled the alternators. Also installed in the powerhouse was a small turbine directly connected to a direct current exciter rated at 200 kw., which supplied power to station's lighting, the crane, as well as the excitation of the generator field. None of these turbines were protected by valves of any kind, though wickets provided some protection.

In 1922, the power company expanded its generating capacity. It constructed a small, one-story addition, measuring about 30' x 58', to the south wall of the original powerhouse. Not as tall as the original powerhouse, the addition measured about 35' in height. The utilitarian concrete structure was built with thin horizontal beams and vertical columns which symetrically framed the walls of windows. Generating units No. 3 and No. 4 were installed in the annex by 1922. Each one, a S. Morgan Smith and Company, Francis-type vertical turbine, was rated at 5,000 horsepower, and was directly connected to 3,330 kva Westinghouse alternating current generators (6,000 volt, 60 cycle, 3 phase, 300 rpm). A Woodward governor regulated the units.

Switchboard

The original switchboard installed in the Elwha powerhouse gallery was destroyed in the October 30, 1912, flood. A second switchboard--a benchboard of the gallery type--was installed in 1913 after repairs were mostly completed to the dam and the power station was ready to go on line. This type of switchboard design allowed the operator to view the machinery and watch the board at the same time. The switchboard controls the station and its outgoing transmission lines. The switchboard occupies 600 square feet in the southeast corner of the generating room. This "switching gallery" is accessible by an iron stairway and supported on cast iron columns, all of which is, in turn, sitting on a 4" inch floor of steel and concrete, reinforced with wire mesh. The main switchboard measures about 8' in height and has a 120 degree arc, forming a circular bench. The various instruments (manufactured by Westinghouse) are mounted on panels made of oil-black slate; the entire switchboard is supported by a structural steel frame, and a curvilinear row of steel Doric columns supported the upright panel section. In addition to containing all of the controller switches for the station, the switchboard indicates the position of the main, remote control-type switches. (In addition to all of the instruments, a sound-proof telephone booth was located next to the switchboard; below the switchboard, on the main floor, are the electric and hand operated generator and exciter rheostats, and solenoid circuit breakers.)

Transformer and High Tension Equipment

Similar to most of the early hydroelectric power plants, the Elwha powerhouse contained transformers. Manufactured by Westinghouse, the transformers are located on the second floor of the building, and are arranged in two banks, for a total of seven, 1,000 kva oil insulated, water-cooled units which step up 6,600 volts to the line voltage of 66,000 volts. The current leaves a low tension switch, passes through Kelman oil switch current breakers, and travels directly through insulating roof bushings to external transmission lines.

HEADWORKS: GLINES CANYON HYDROELECTRIC PROJECT

Dam
A single-arch dam, the Glines Canyon Dam combined both beauty and utility when it was completed in 1927. It measures about 200' in height. (The original walkway extended 10' higher bringing the total height to 210'.) The base of the dam measures about 55' in length, and its crest measures 152' in length, excluding the concrete abutment on its east end and the spillway section on its west end. The abutment anchors the dam to the steep canyon wall; and an earthen berm extends to the east. The dam's west wall contains the spillway section, measuring 121' in length. The spillway section has five tainter gates which measure 18' x 20'.

Water Conveyance System
The water conveyance system is made up of an intake, power tunnel, gatehouse, pressure pipe, surge tank, and penstock. The intake is located 83' below the crest of the dam and is covered by a trash rack and raking equipment measuring 20' x 40'. The concrete gatehouse measures 20' x 20'. The entire length of the power tunnel, pressure pipe, and penstock measures about 1426' in length. The power tunnel, which cuts through solid rock, is the longest component, measuring 569', and measures in a cross section is 13' x 14'. The pressure pipe, made of steel, measures 321' in length and is 10' in diameter. The steel penstock, which runs from the surge tank to the powerhouse, measures 11'-6" in diameter and about 159' in length. A Johnson differential-type surge tank is located between the pressure pipe and the penstock. It measures 50' in height and 20' in diameter with an interior riser of 9' in diameter. The power tunnel system contains a control gate located 190' down from the intake, and an 8'-6" butterfly valve at the inlet to the turbine casing.

Powerhouse
A reinforced concrete structure, the powerhouse is sited about 800' downriver from the dam, measures 40' x 60', and contains all of the generating equipment except the substation equipment. Designed to hold one generating unit and all of its accompanying electrical equipment, the powerhouse contains a single, vertical shaft Francis type turbine, manufactured by the Pelton Water Wheel Company, and is rated at 17,500 horsepower under a 180' head. It drives a General Electric vertical, alternating current generator rated at 13,333 kva with a direct connected exciter. An auxiliary water wheel, designed to furnish the power plant's lighting and power needs when the main unit is shut down, drives a 62.5 kva, 220 volt combination motor and generator.

Transformer Station

The outside transformer station is located a short distance from the powerhouse. It contains three General Electric 4,500 kva transformers, which raise the voltage from 6,600 to 66,000 volts. The electricity is then transmitted to the Elwha station approximately 7 miles downriver.